US011217413B2

(12) **United States Patent**
Darr et al.

(10) **Patent No.: US 11,217,413 B2**
(45) **Date of Patent: Jan. 4, 2022**

(54) **ELECTRONICALLY CONTROLLED FUSIBLE SWITCHING DISCONNECT MODULES AND DEVICES**

(75) Inventors: **Matthew Rain Darr**, Edwardsville, IL (US); **Hundi Panduranga Kamath**, Los Altos, CA (US)

(73) Assignee: **EATON INTELLIGENT POWER LIMITED**, Dublin (IE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 582 days.

(21) Appl. No.: **13/008,940**

(22) Filed: **Jan. 19, 2011**

(65) **Prior Publication Data**

US 2011/0163836 A1 Jul. 7, 2011

Related U.S. Application Data

(60) Continuation-in-part of application No. 12/277,051, filed on Nov. 24, 2008, now Pat. No. 7,924,136, (Continued)

(51) **Int. Cl.**

H01H 71/20	(2006.01)
H01H 85/045	(2006.01)
H01H 1/20	(2006.01)
H01H 9/10	(2006.01)
H01H 9/28	(2006.01)
H01H 21/16	(2006.01)
H01H 71/04	(2006.01)
H01H 71/08	(2006.01)
H01H 71/12	(2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***H01H 71/20*** (2013.01); ***H01H 1/20*** (2013.01); ***H01H 9/10*** (2013.01); ***H01H 9/104*** (2013.01); ***H01H 9/282*** (2013.01); ***H01H 21/16*** (2013.01); ***H01H 71/04*** (2013.01); ***H01H 71/08*** (2013.01); ***H01H 71/123*** (2013.01); ***H01H 71/125*** (2013.01); ***H01H 83/12*** (2013.01); *H01H 9/102* (2013.01); *H01H 83/10* (2013.01); *H01H 85/0241* (2013.01); *H01H 2071/0278* (2013.01)

(58) **Field of Classification Search**

CPC H01H 9/10; H01H 9/104; H01H 21/16; H01H 71/123; H01H 71/125; H01H 71/04; H01H 1/20; H01H 9/102; H01H 9/282; H01H 2071/0278; H01H 71/08; H01H 83/10; H01H 83/12; H01H 85/0241

USPC 337/8, 143, 186, 187

See application file for complete search history.

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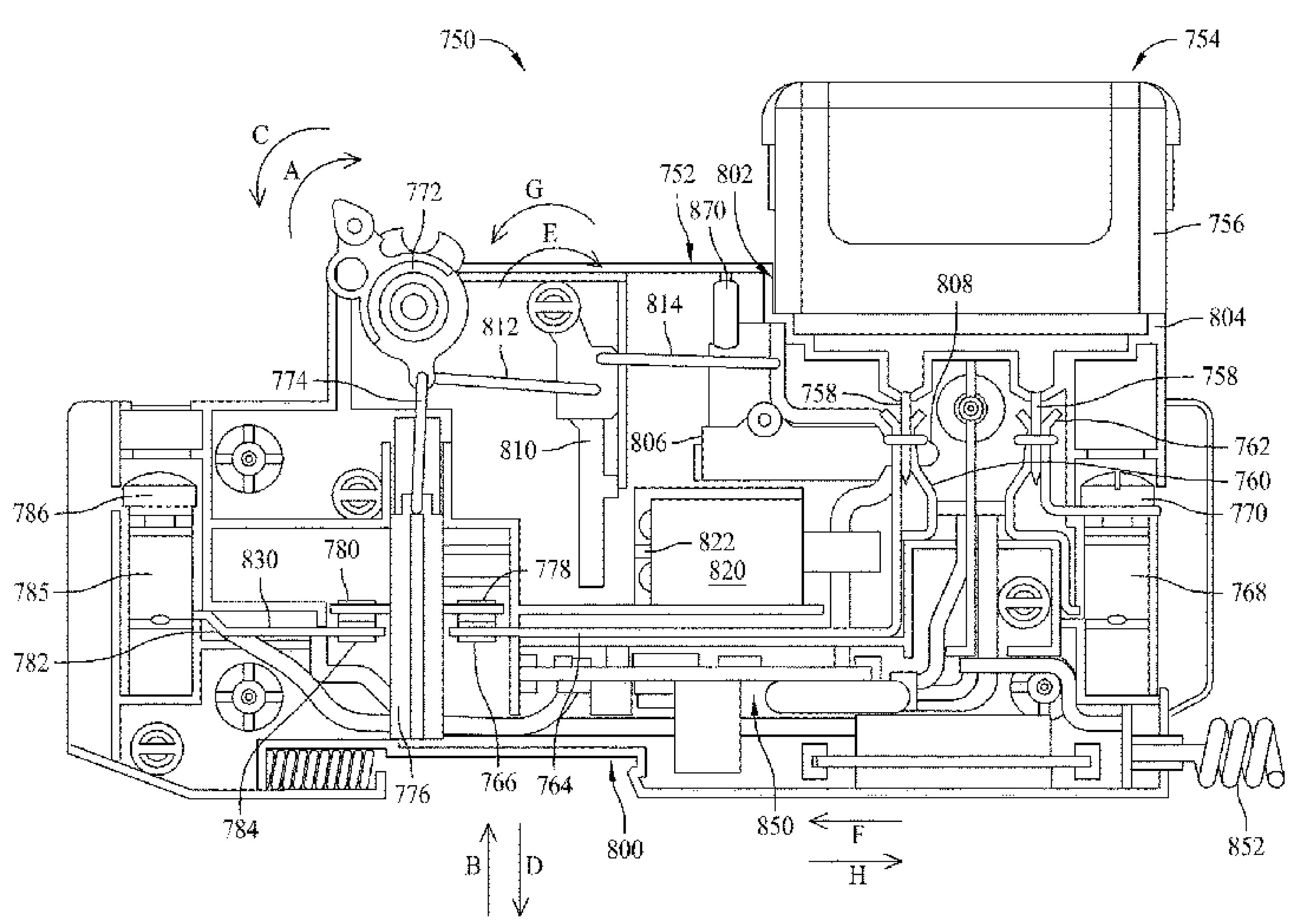
Primary Examiner — Anatoly Vortman
(74) *Attorney, Agent, or Firm* — Armstrong Teasdale LLP

(57) **ABSTRACT**

A fusible switch disconnect device includes a housing adapted to receive at least one fuse therein, and a switchable contact for connecting the fuse to circuitry. A tripping mechanism and control circuitry are provided to move the switchable contact to an open position in response to a predetermined electrical condition.

58 Claims, 35 Drawing Sheets



Related U.S. Application Data

which is a division of application No. 11/274,003, filed on Nov. 15, 2005, now Pat. No. 7,474,194, which is a continuation-in-part of application No. 11/222,628, filed on Sep. 9, 2005, now Pat. No. 7,495,540.

(60) Provisional application No. 60/609,431, filed on Sep. 13, 2004.

(51) **Int. Cl.**

H01H 83/12	(2006.01)
H01H 71/02	(2006.01)
H01H 85/02	(2006.01)
H01H 83/10	(2006.01)

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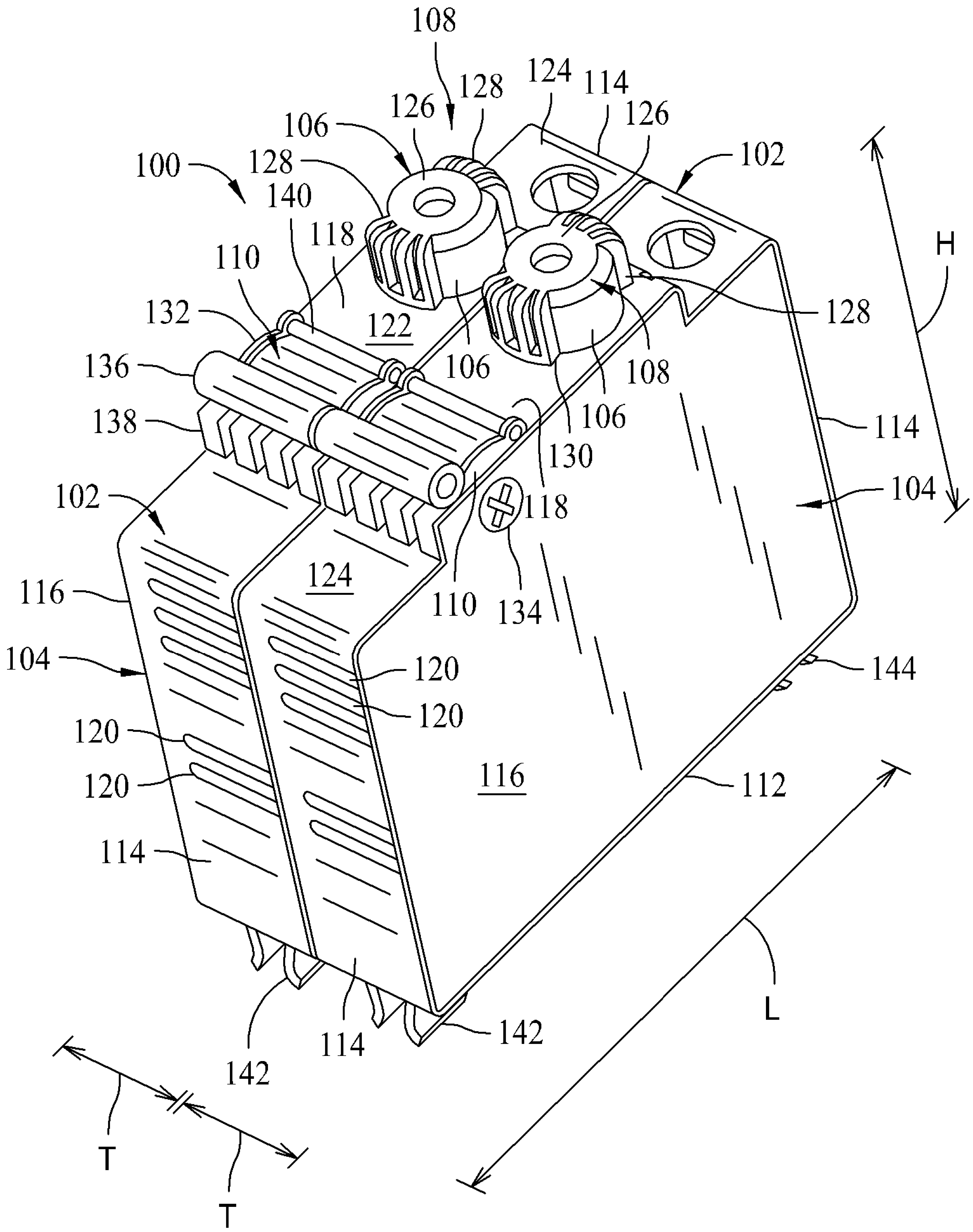

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FIG. 1

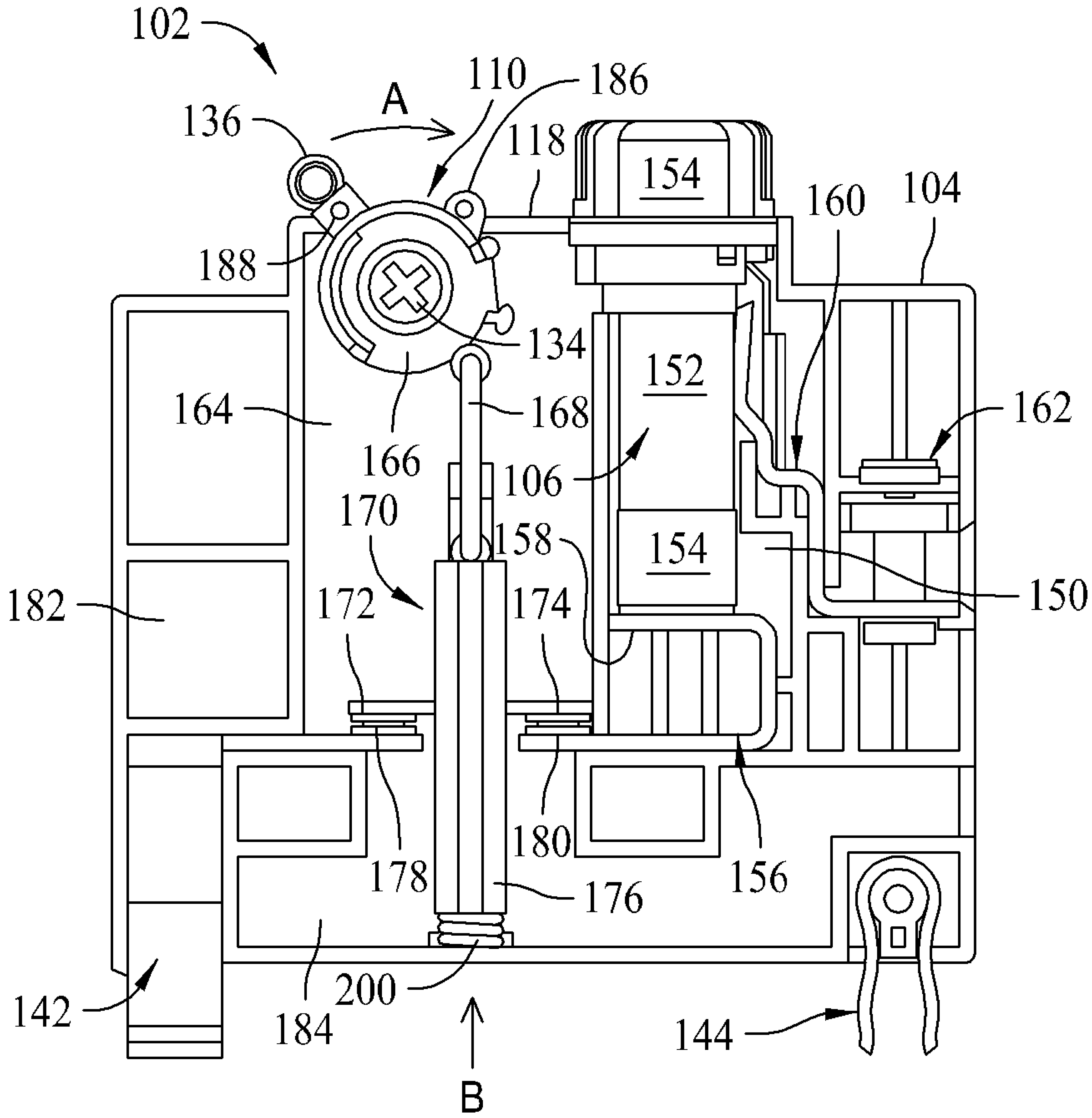
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FIG. 2

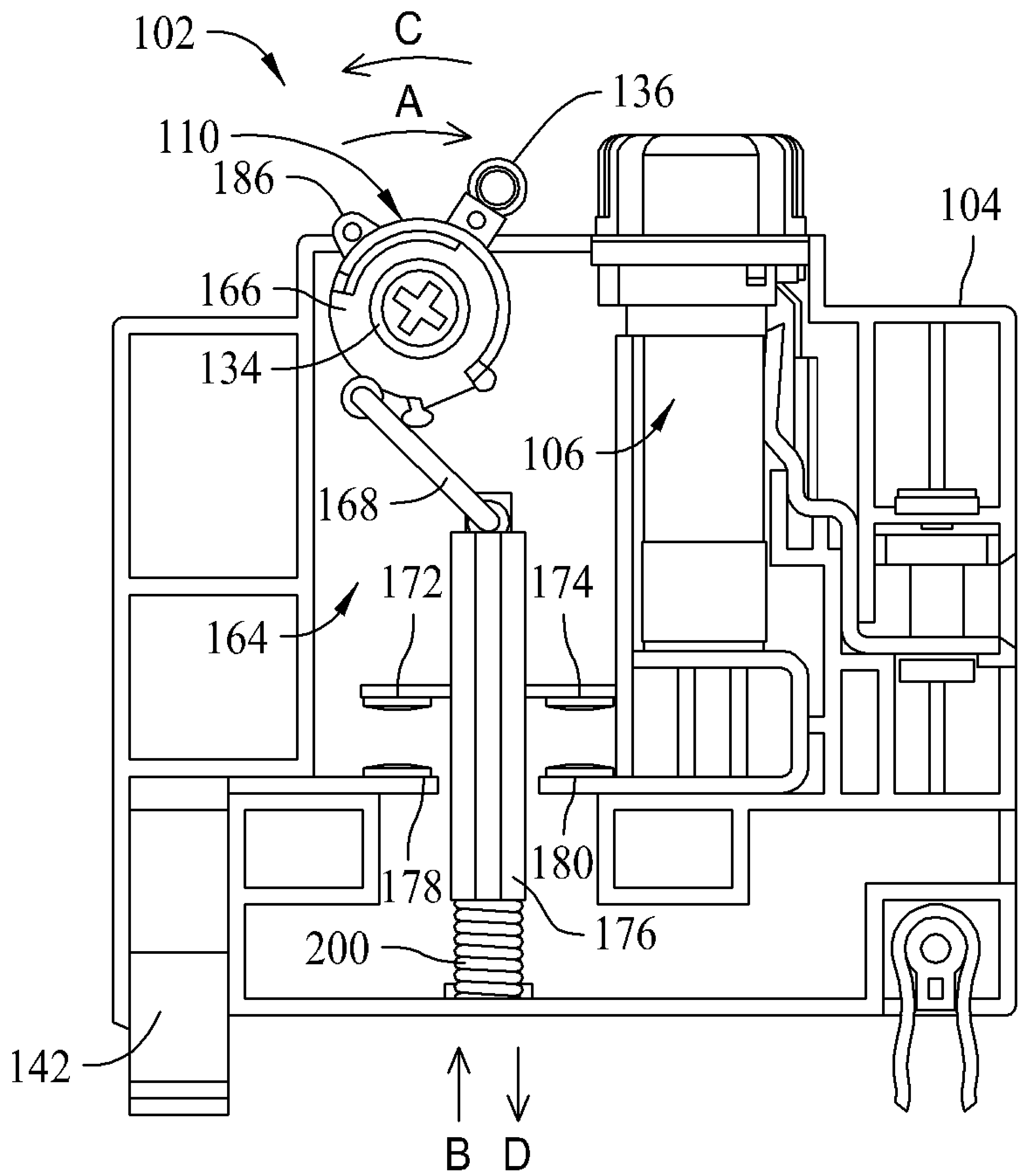
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FIG. 3

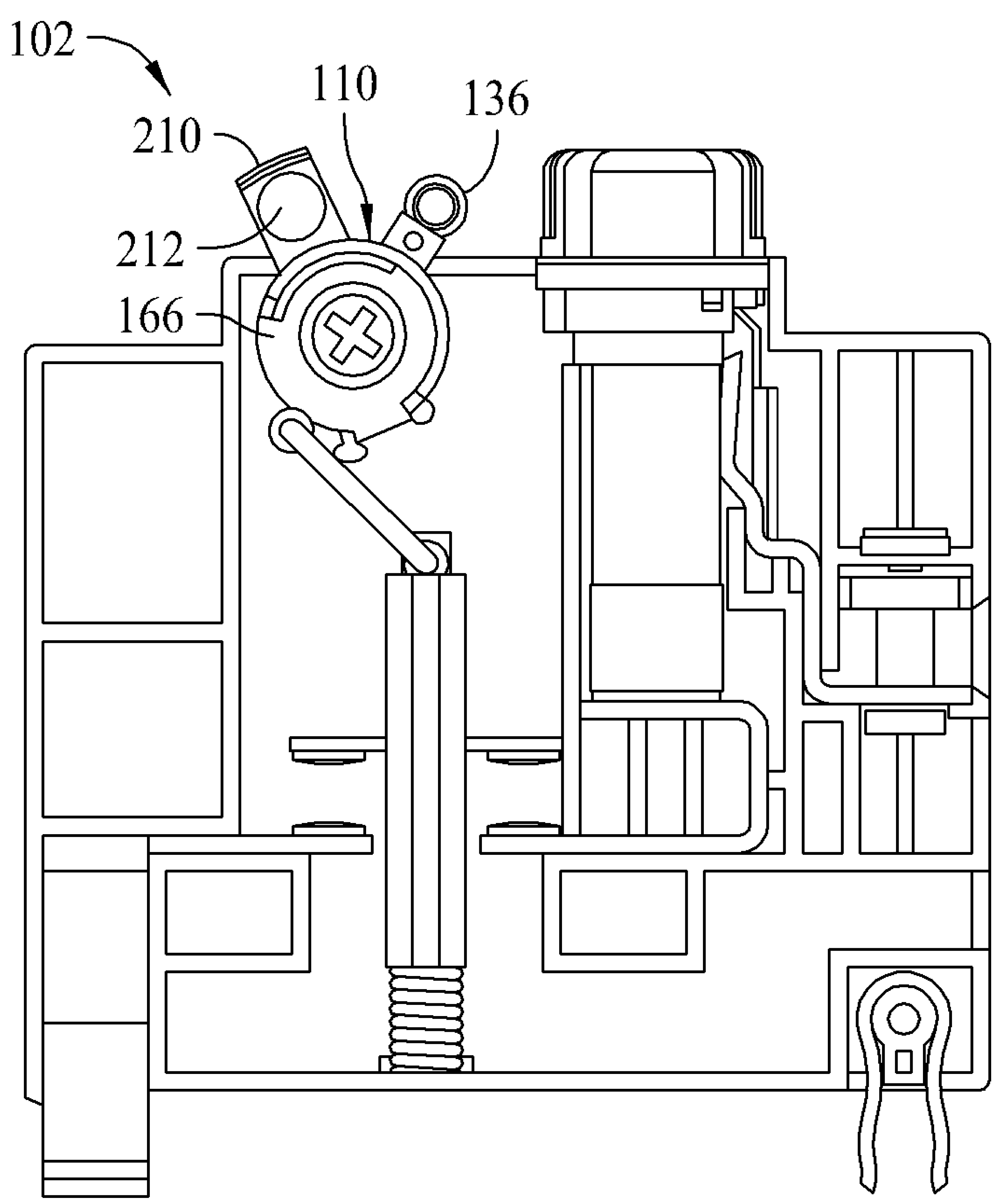
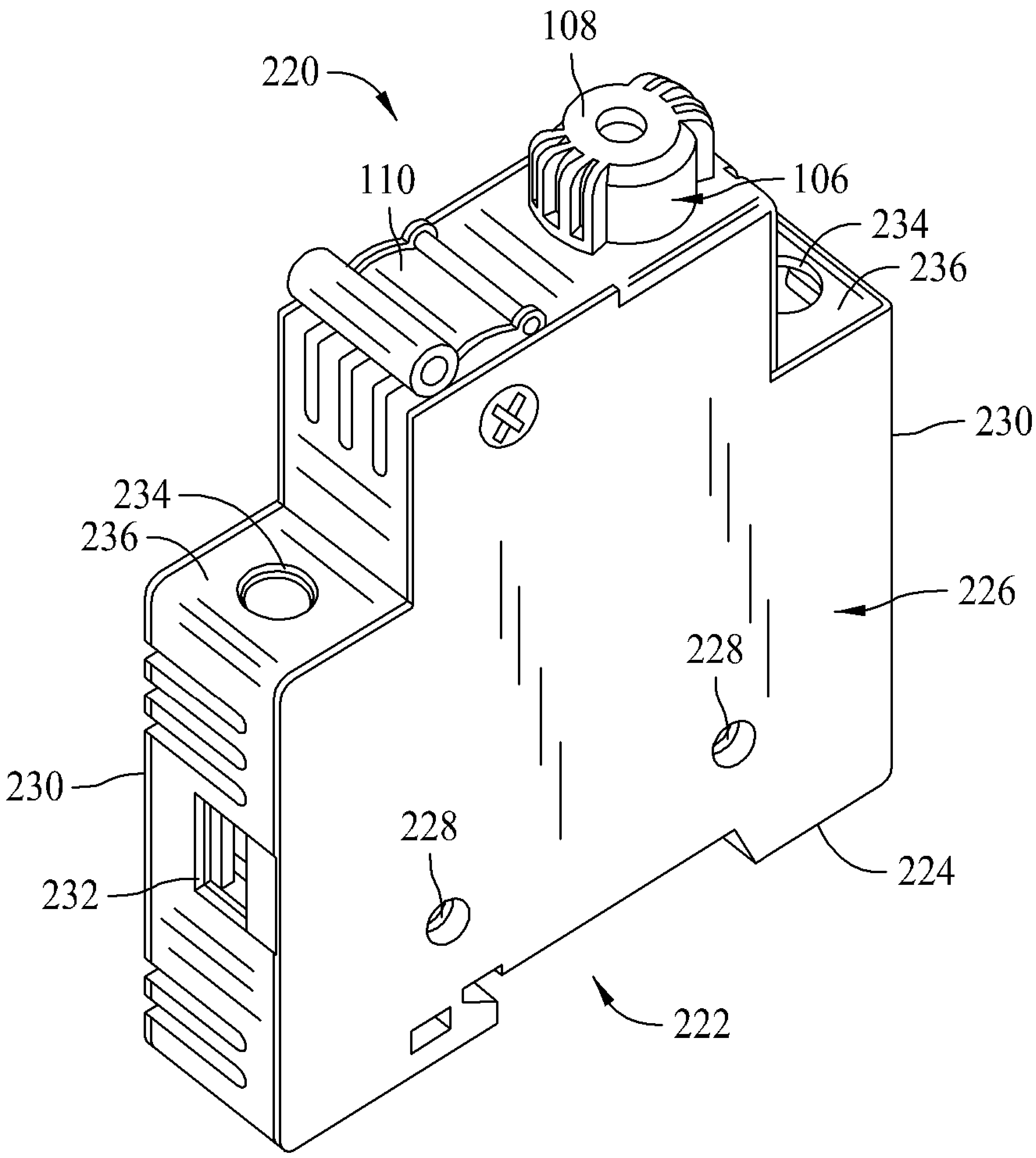


FIG. 4



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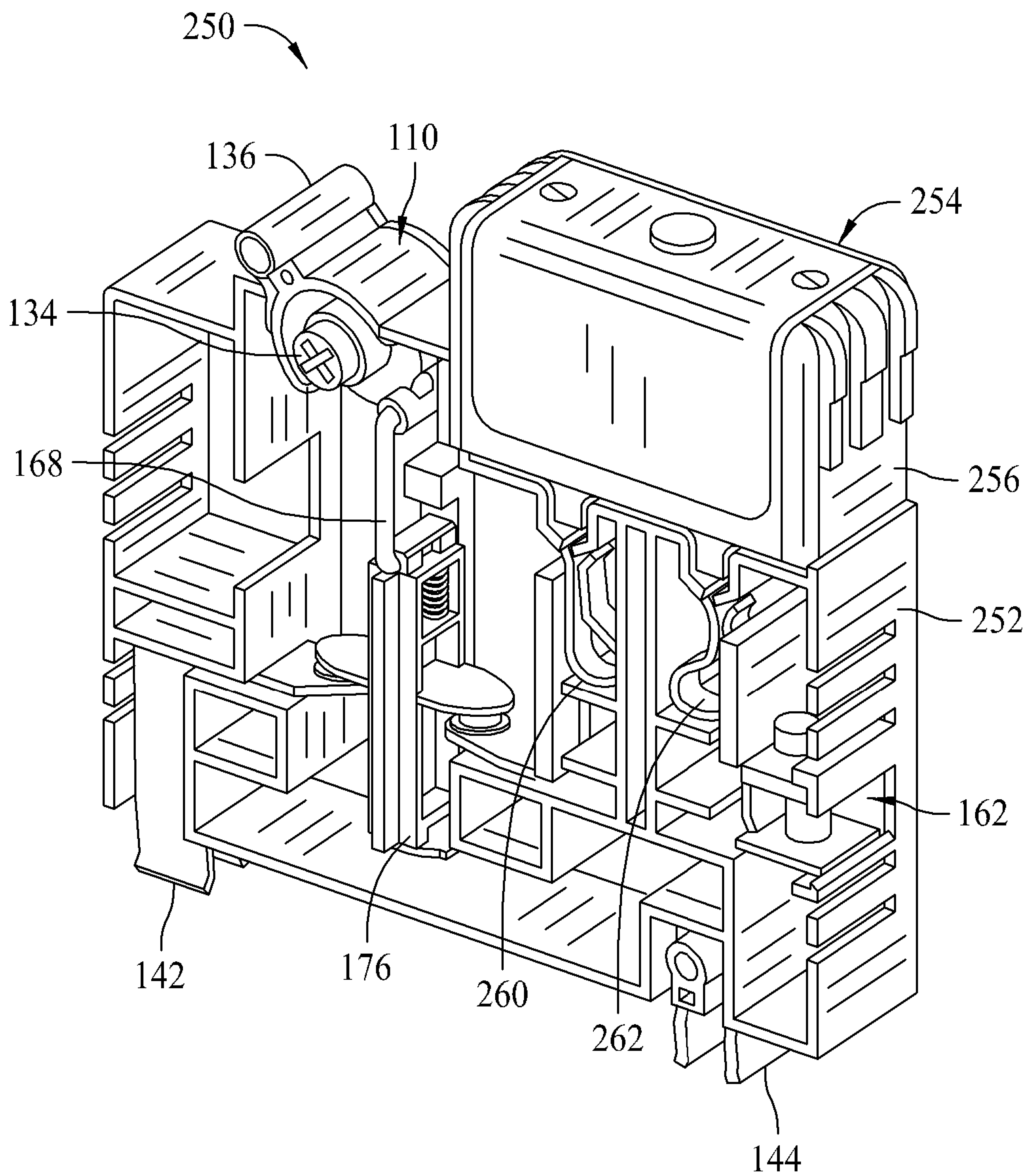

FIG. 6

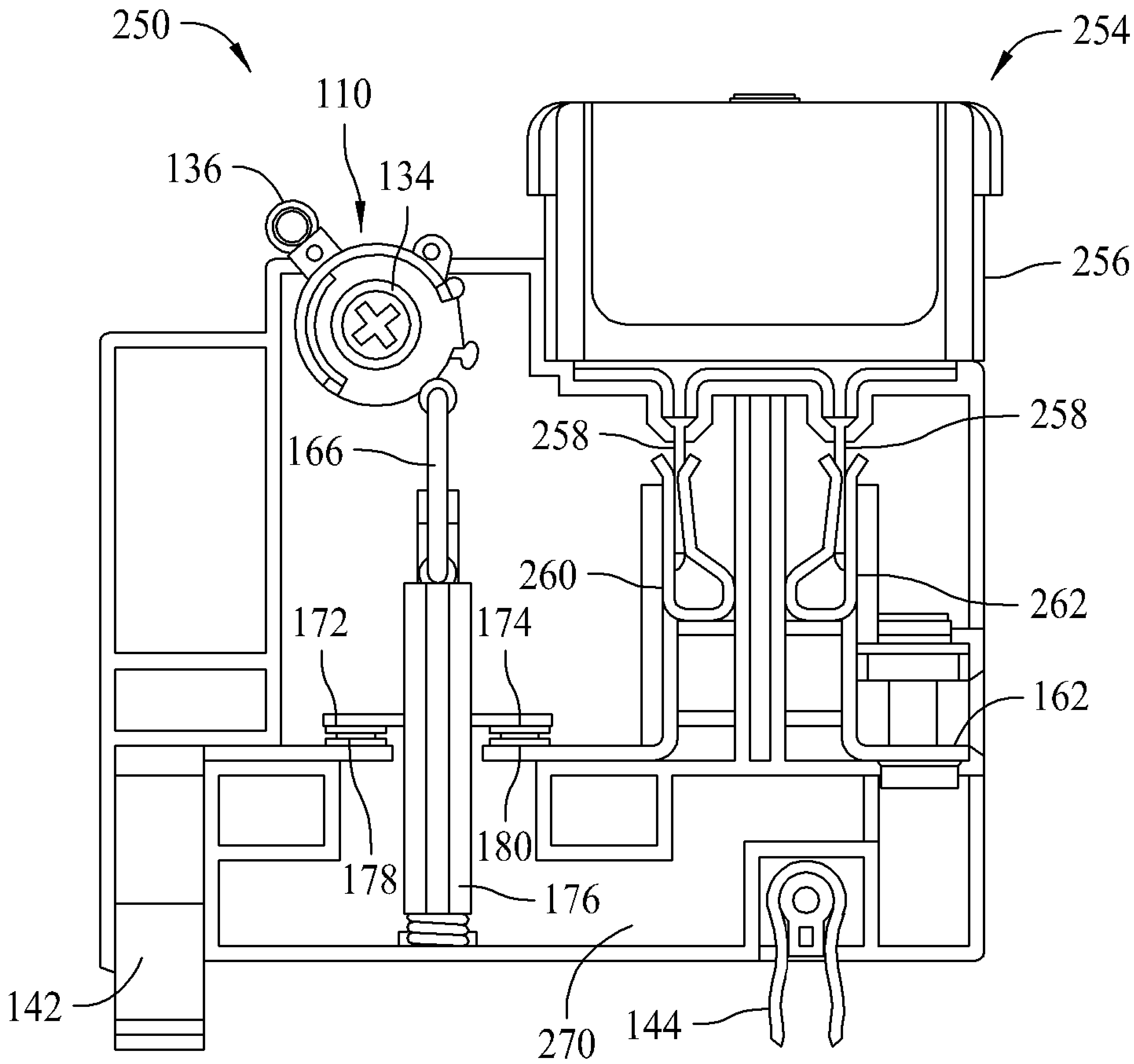
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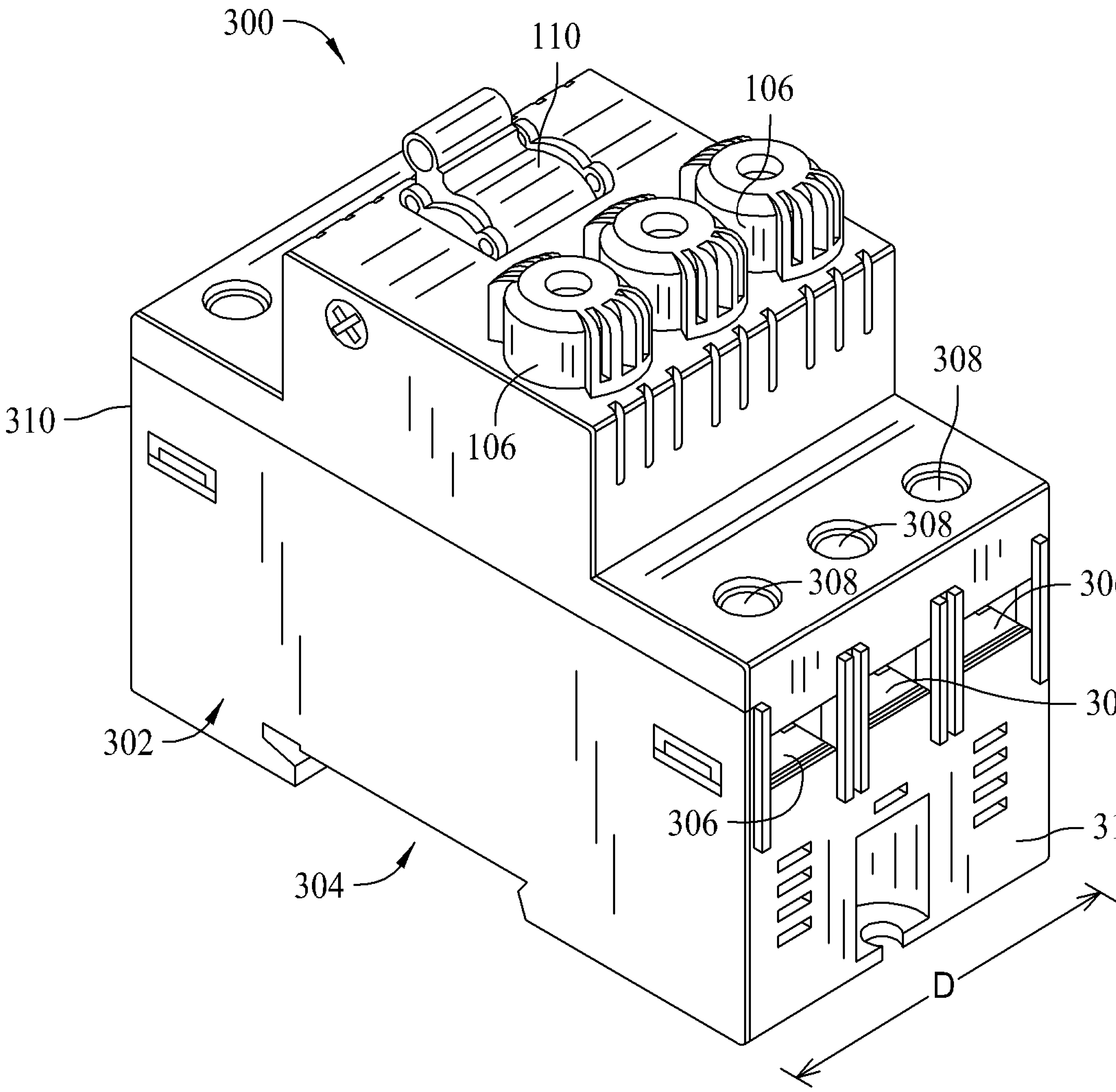
FIG. 7



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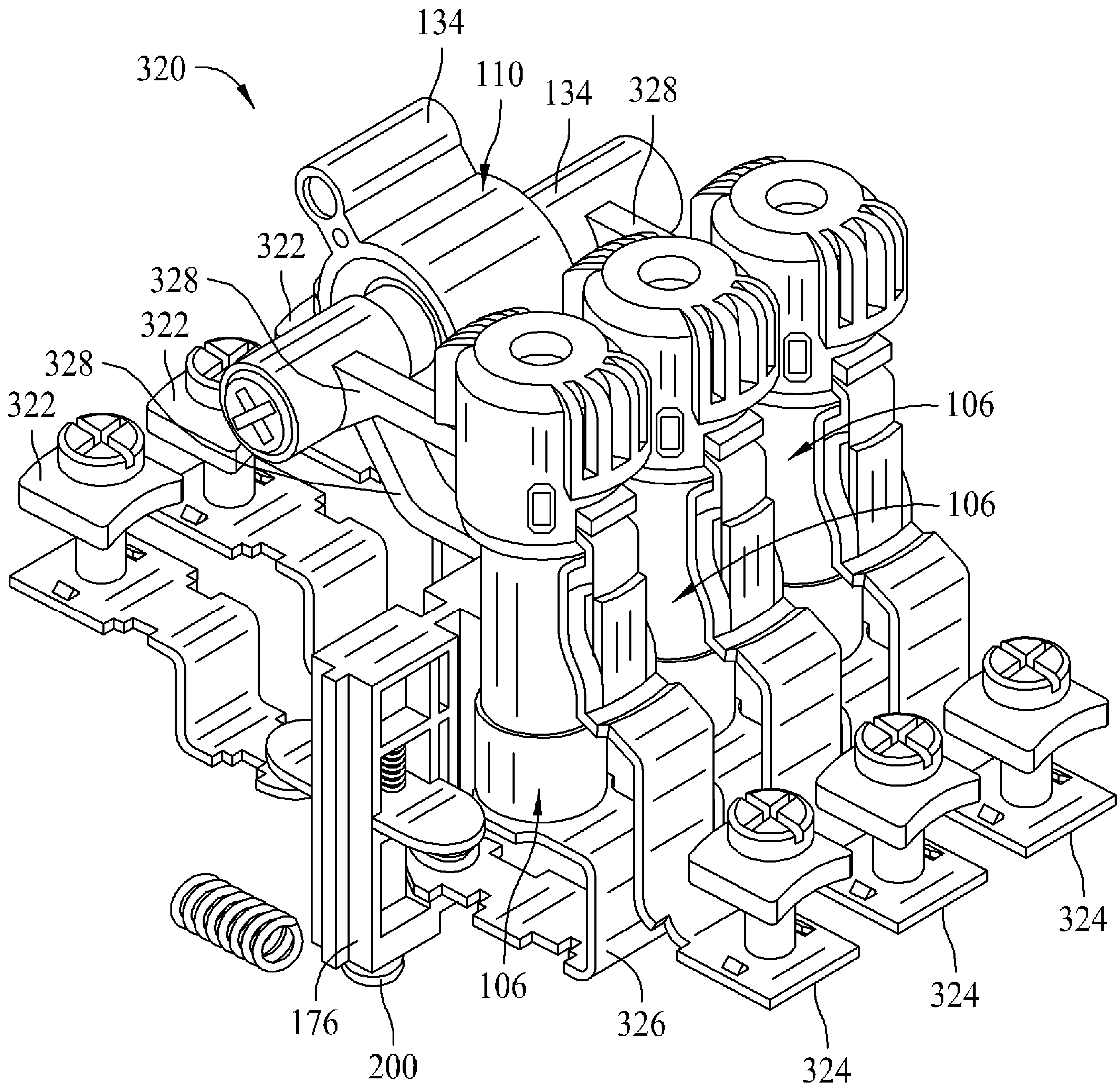
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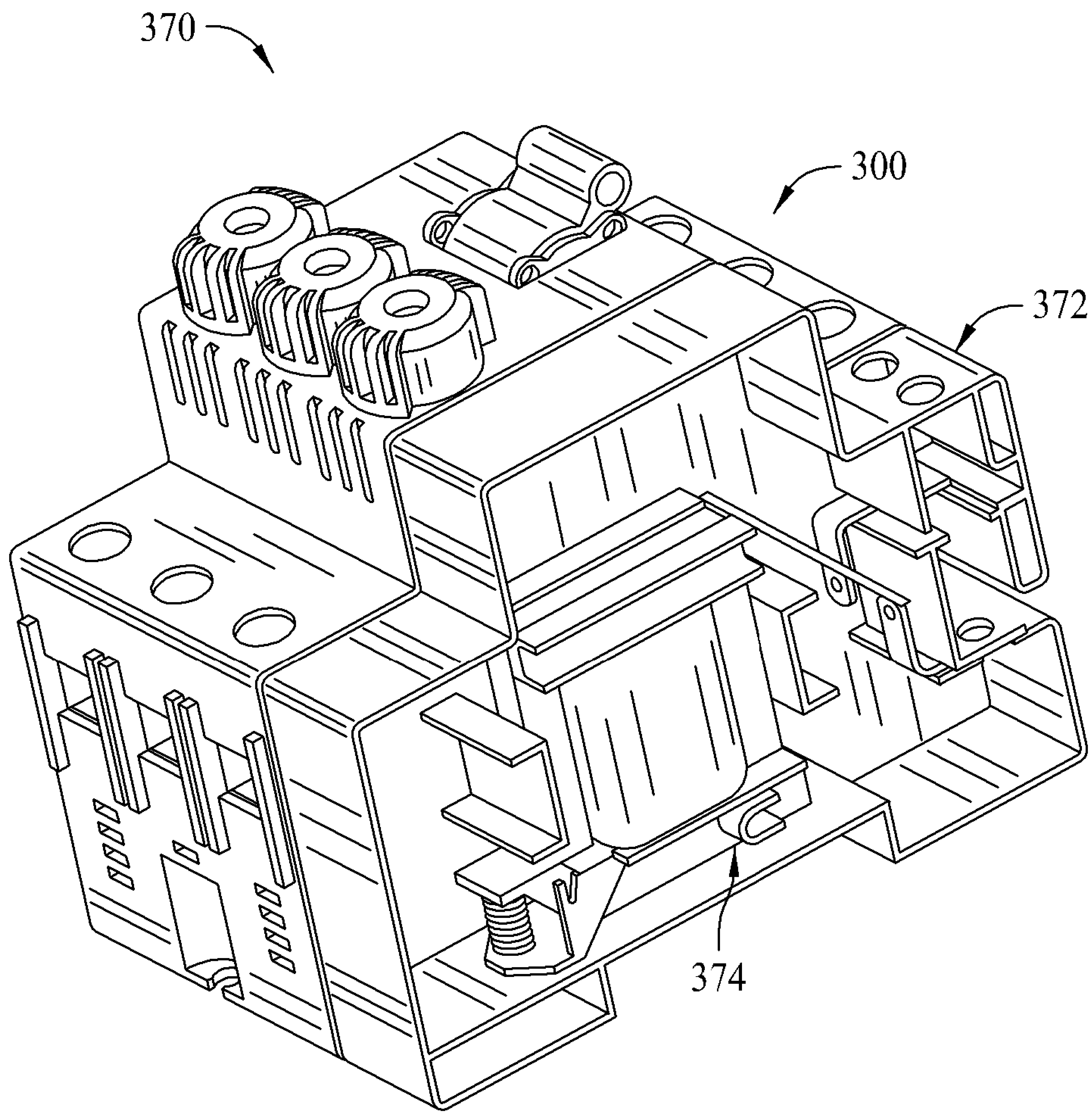
FIG. 9



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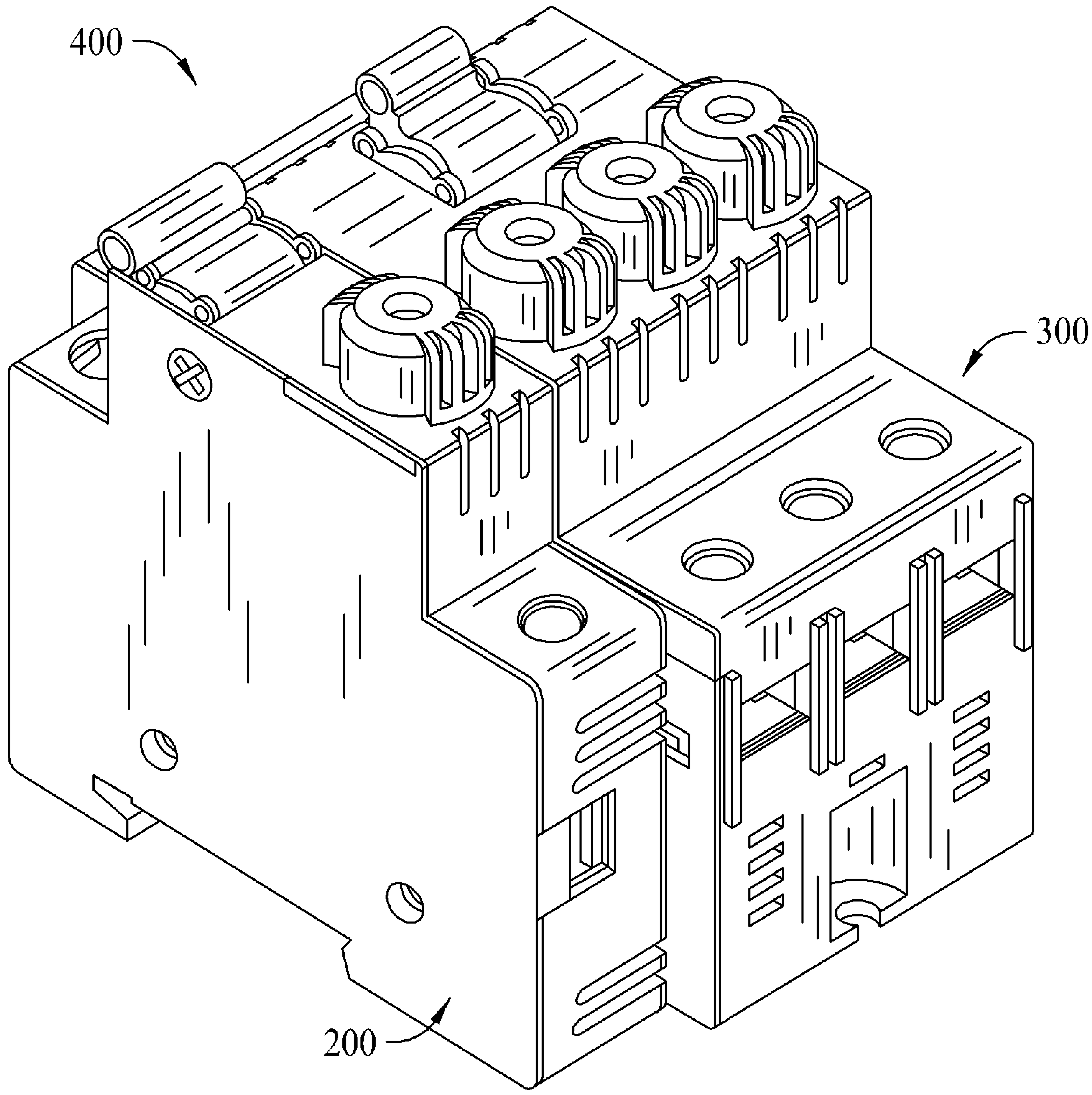

FIG. 11

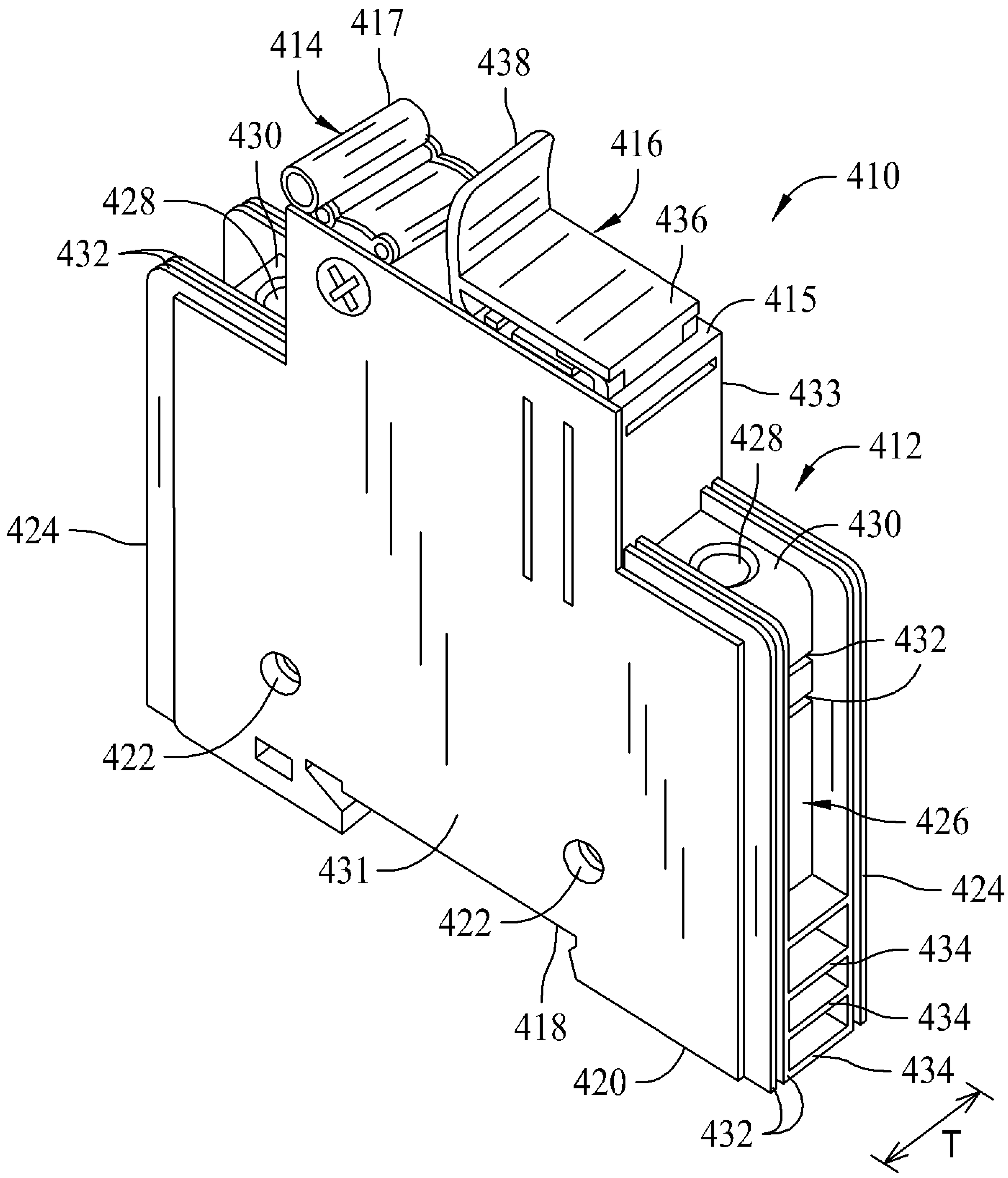
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FIG. 12

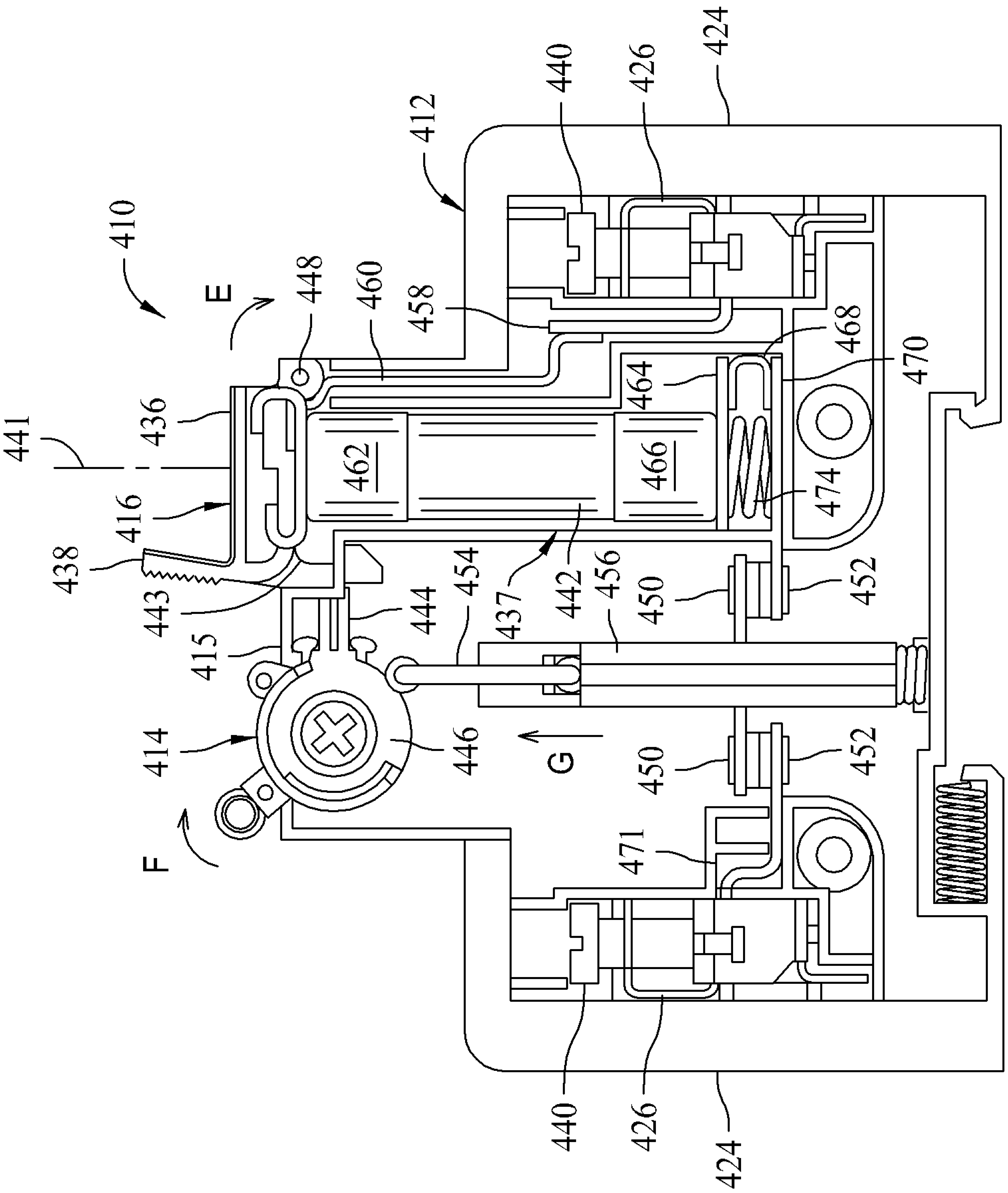
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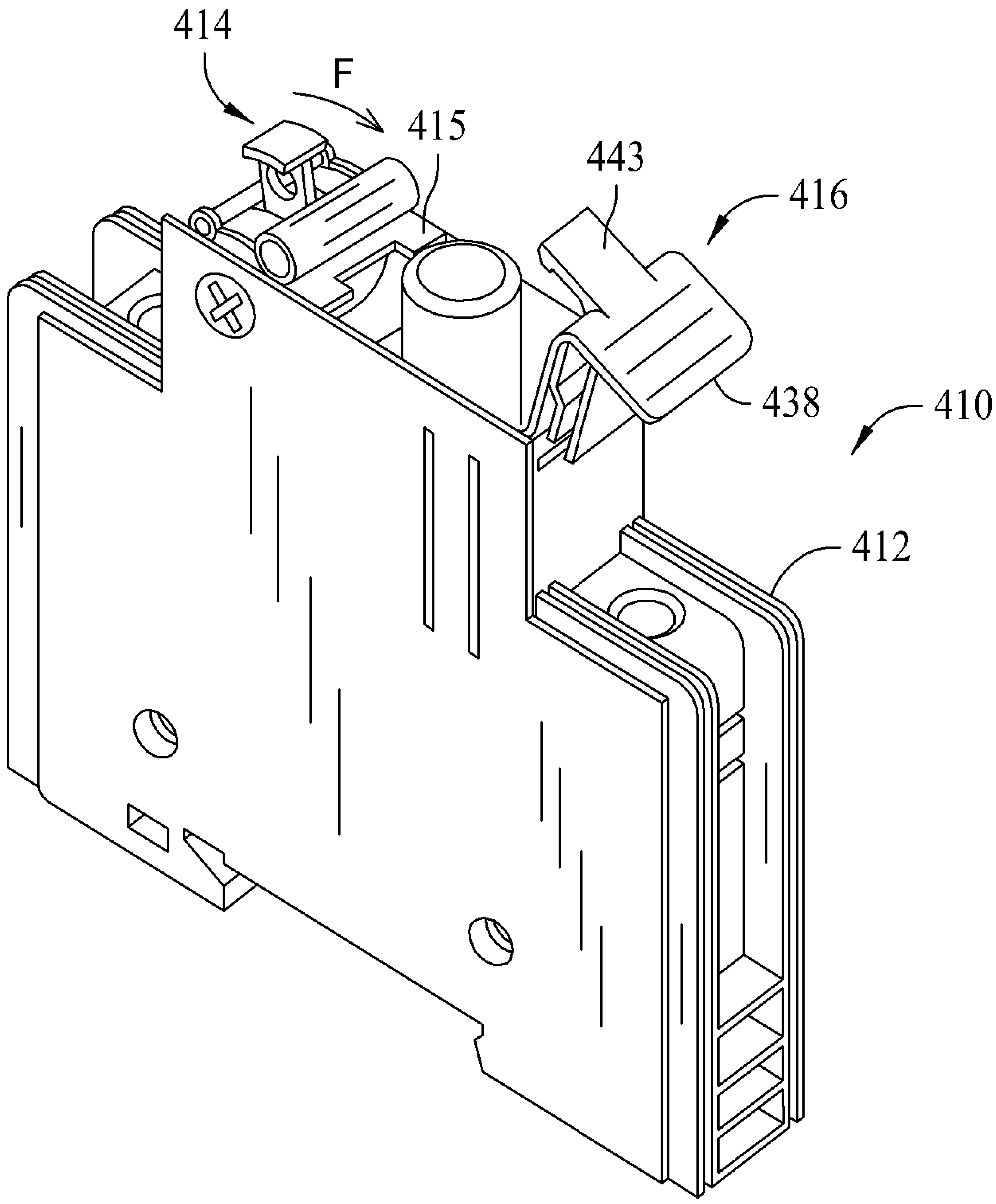
FIG. 13



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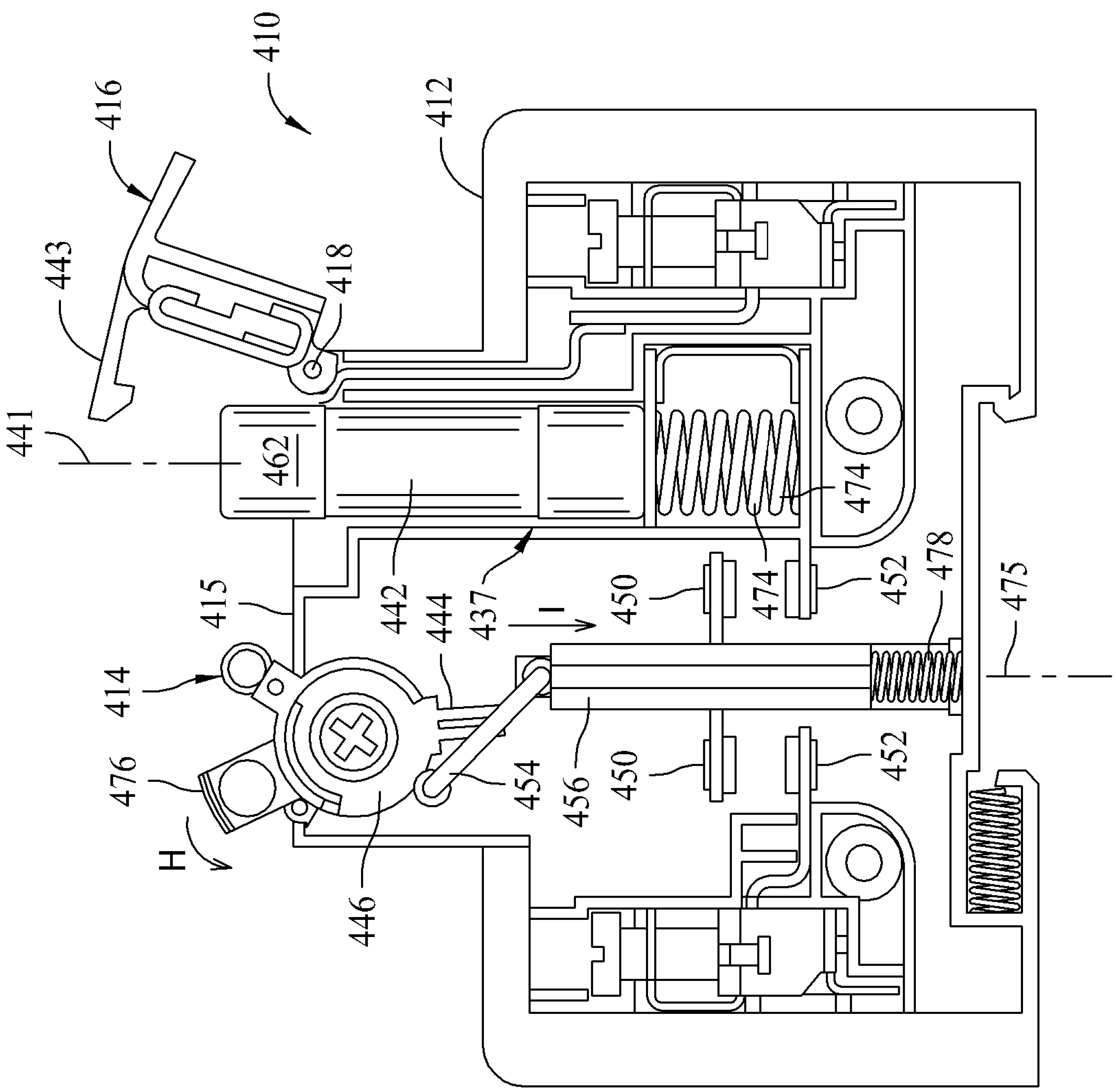
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FIG. 15

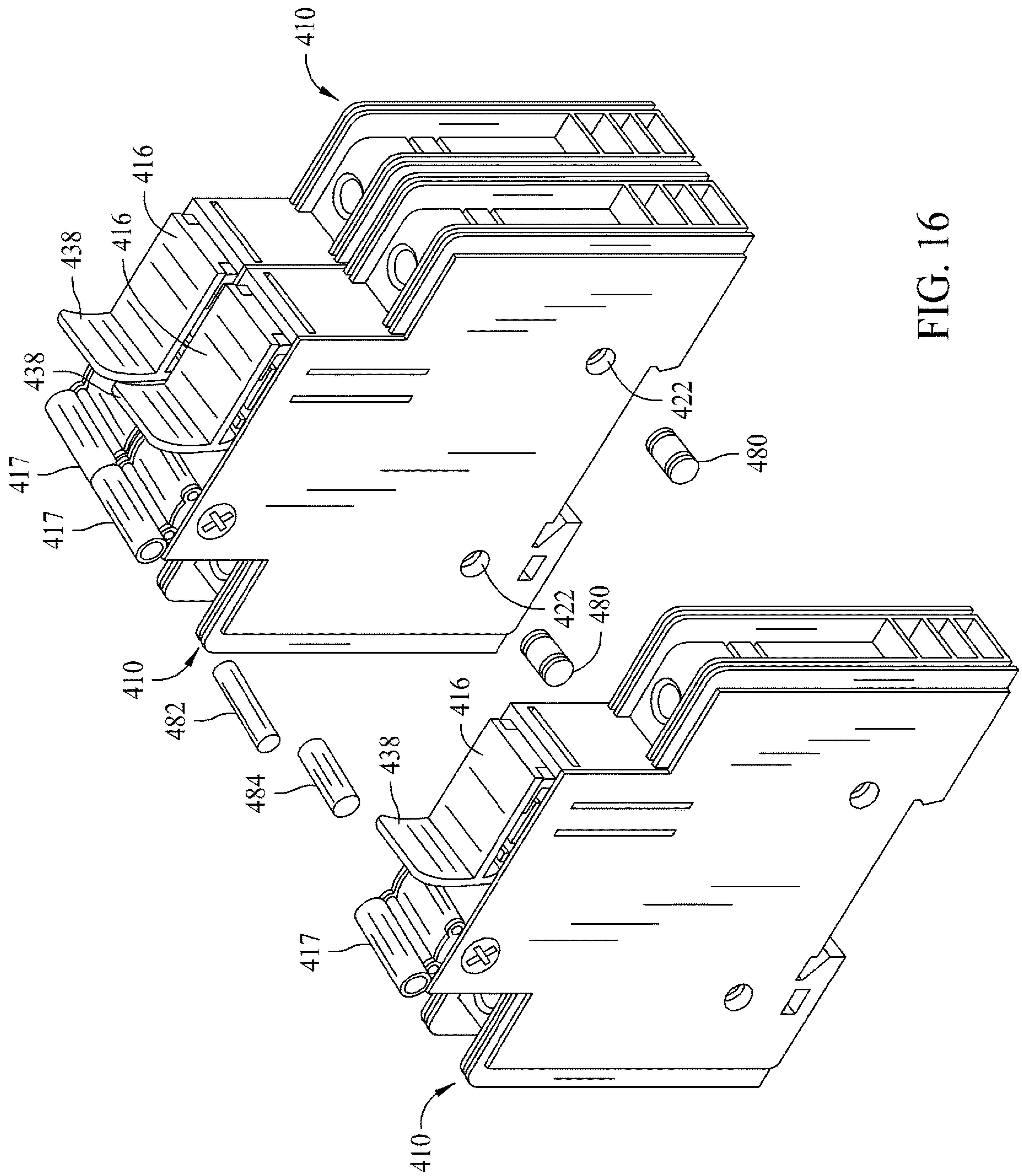
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FIG. 16

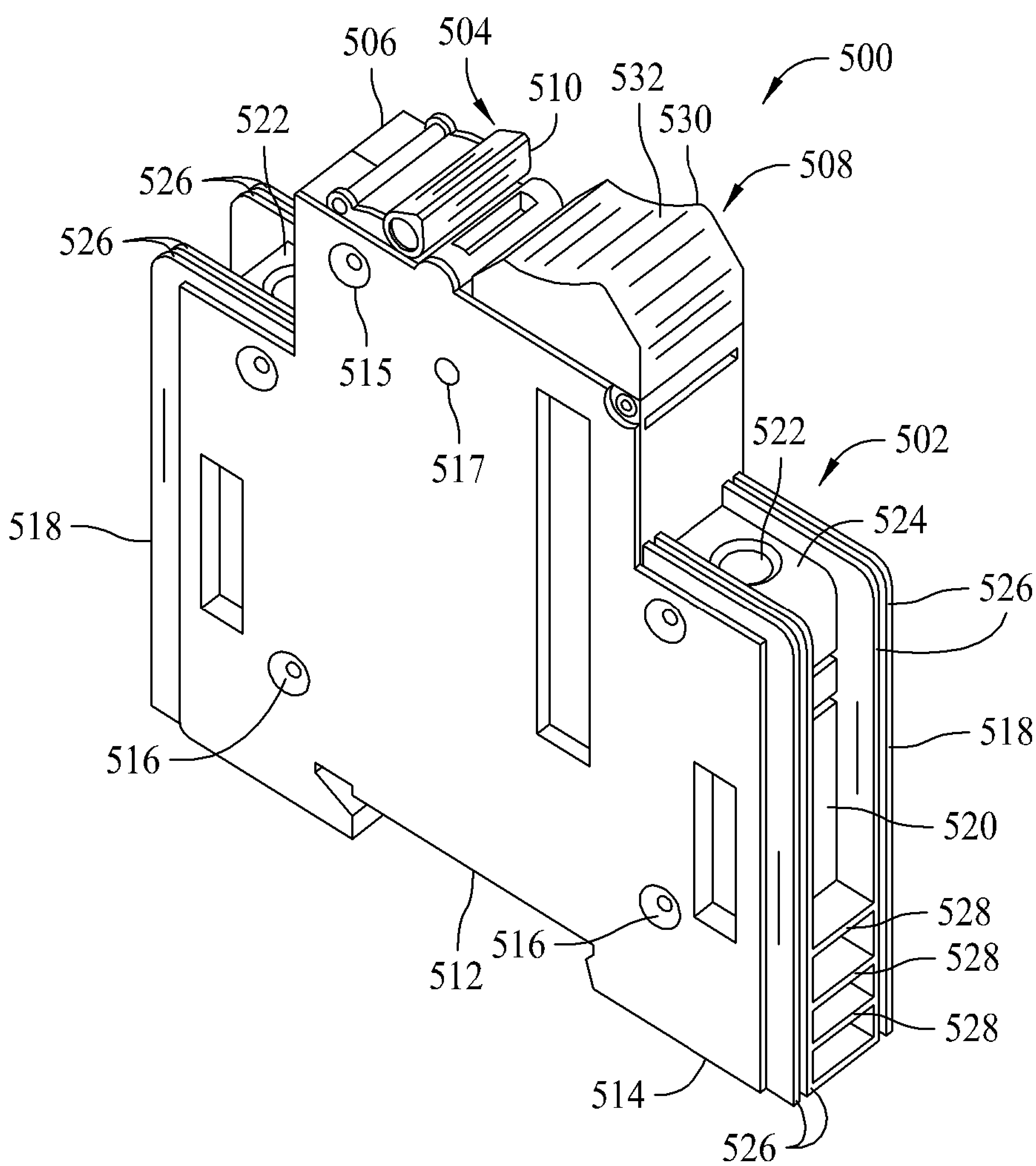

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FIG. 17

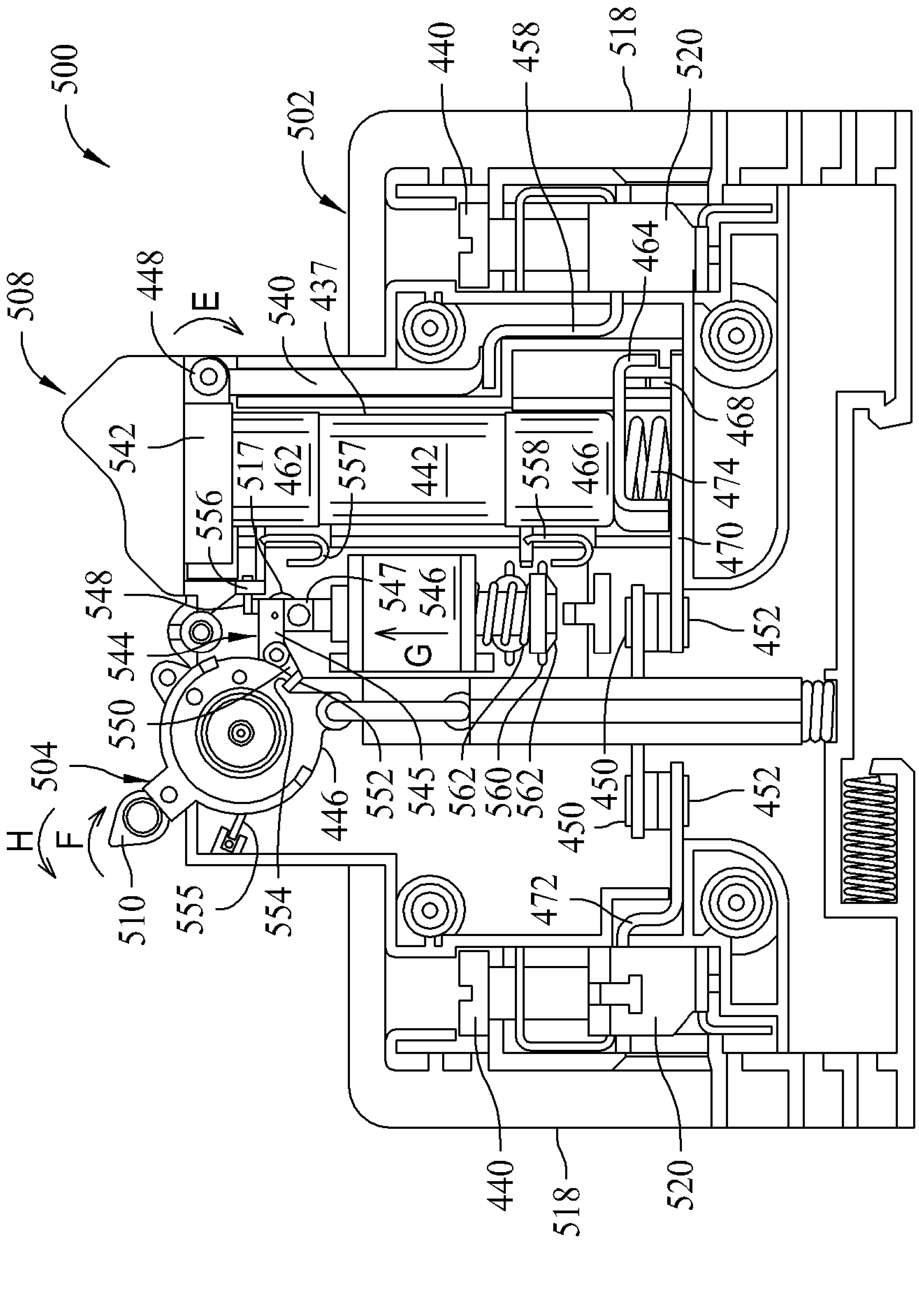
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FIG. 18

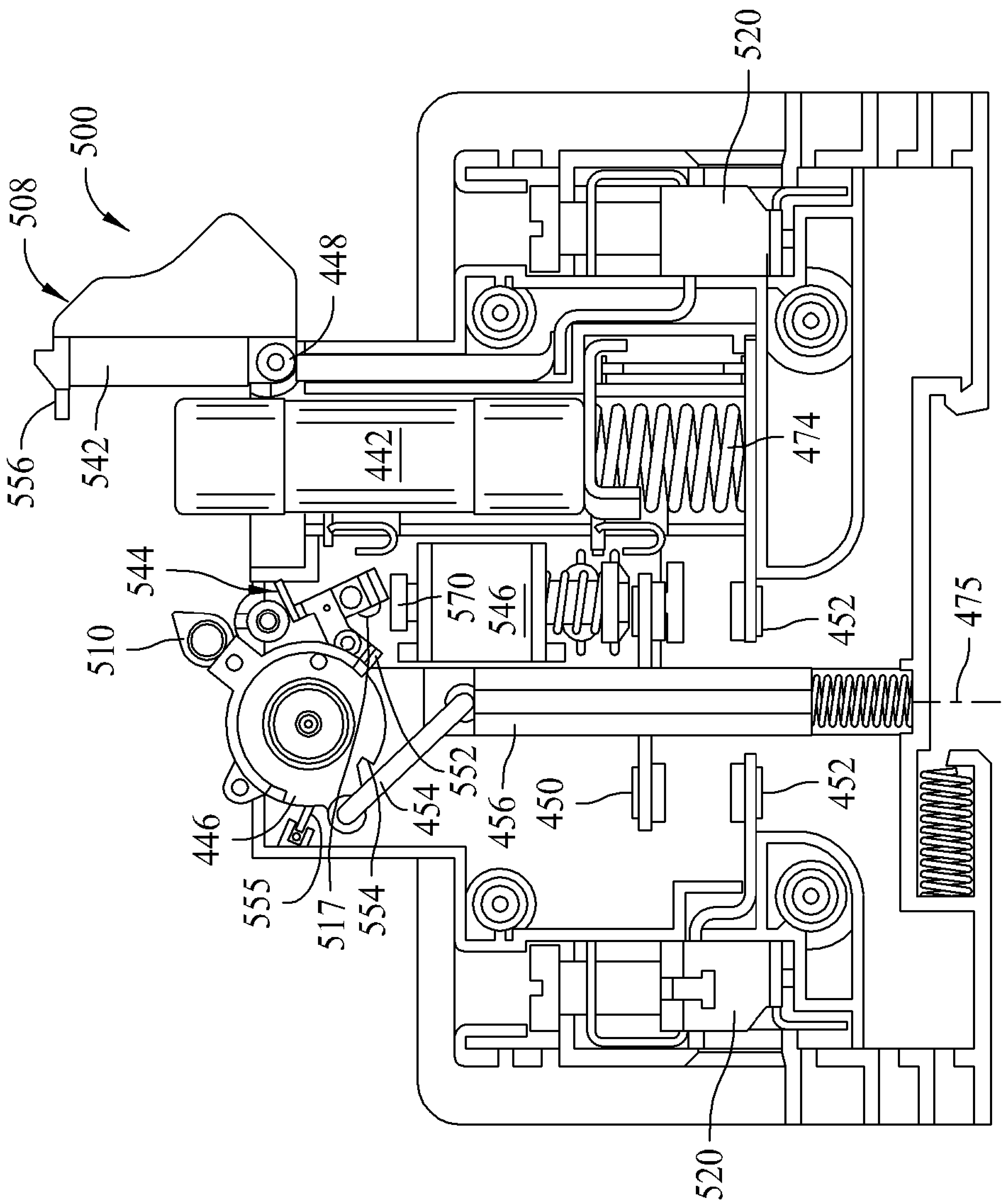

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FIG. 19

FIG. 20

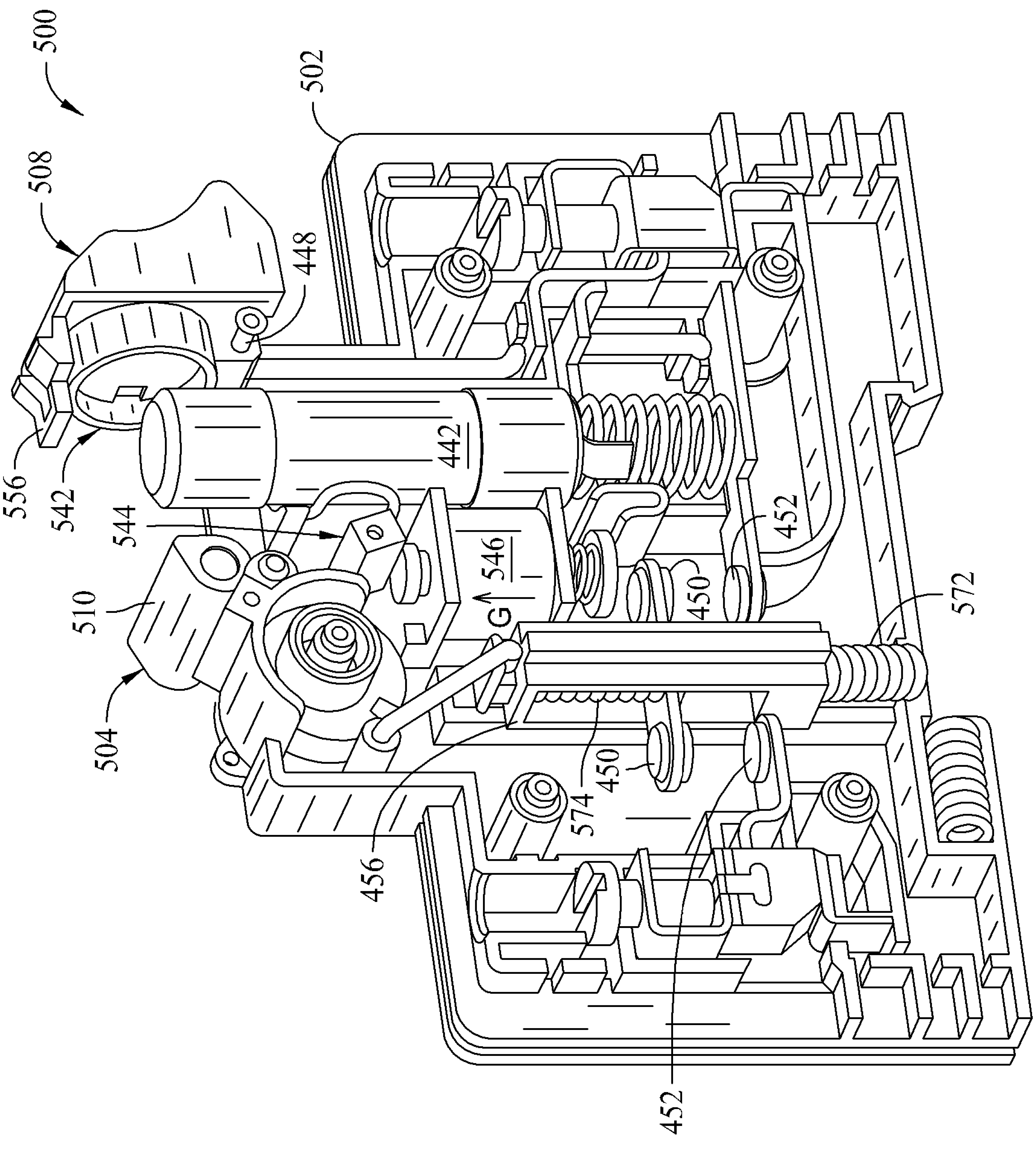
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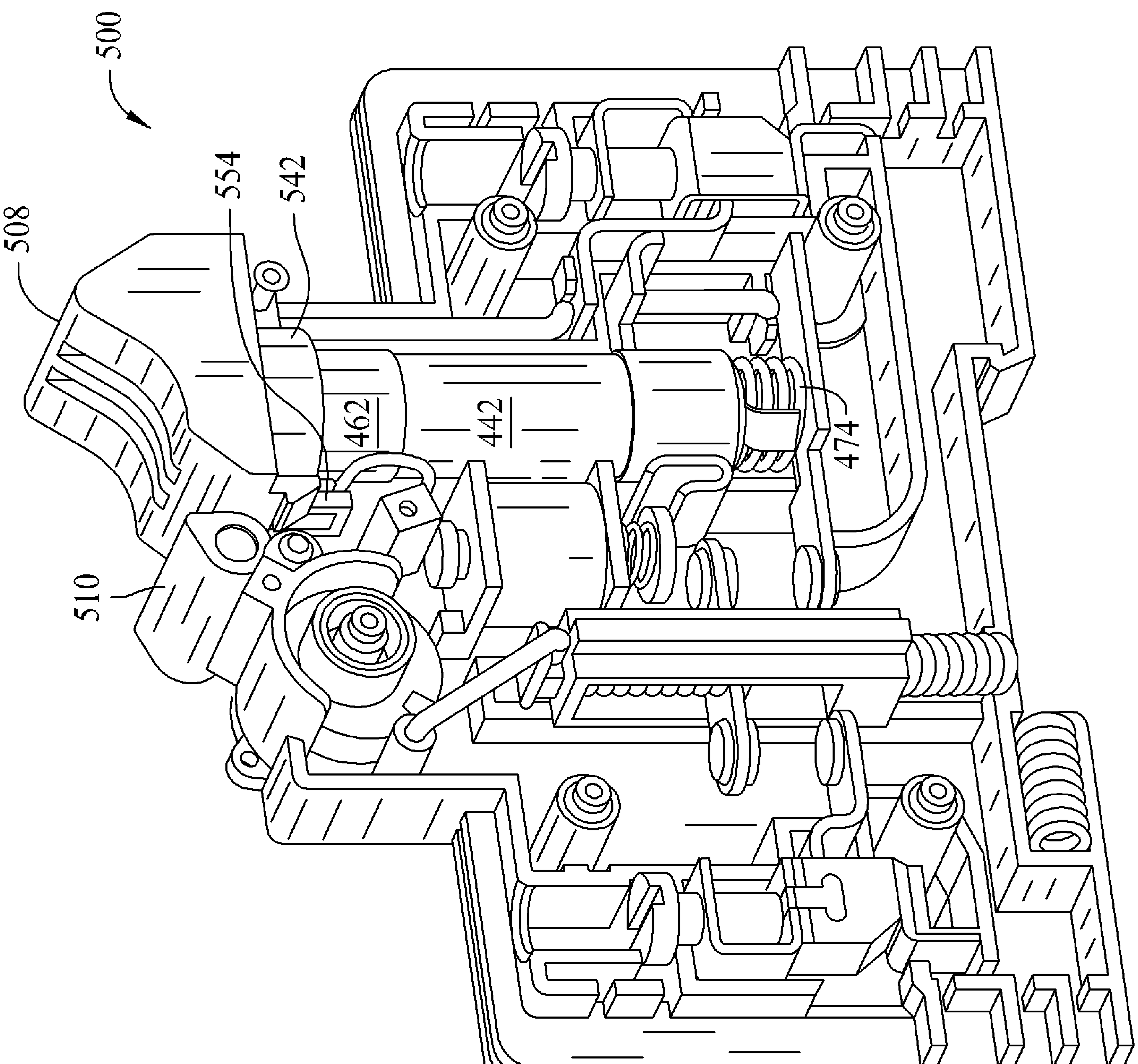
FIG. 21



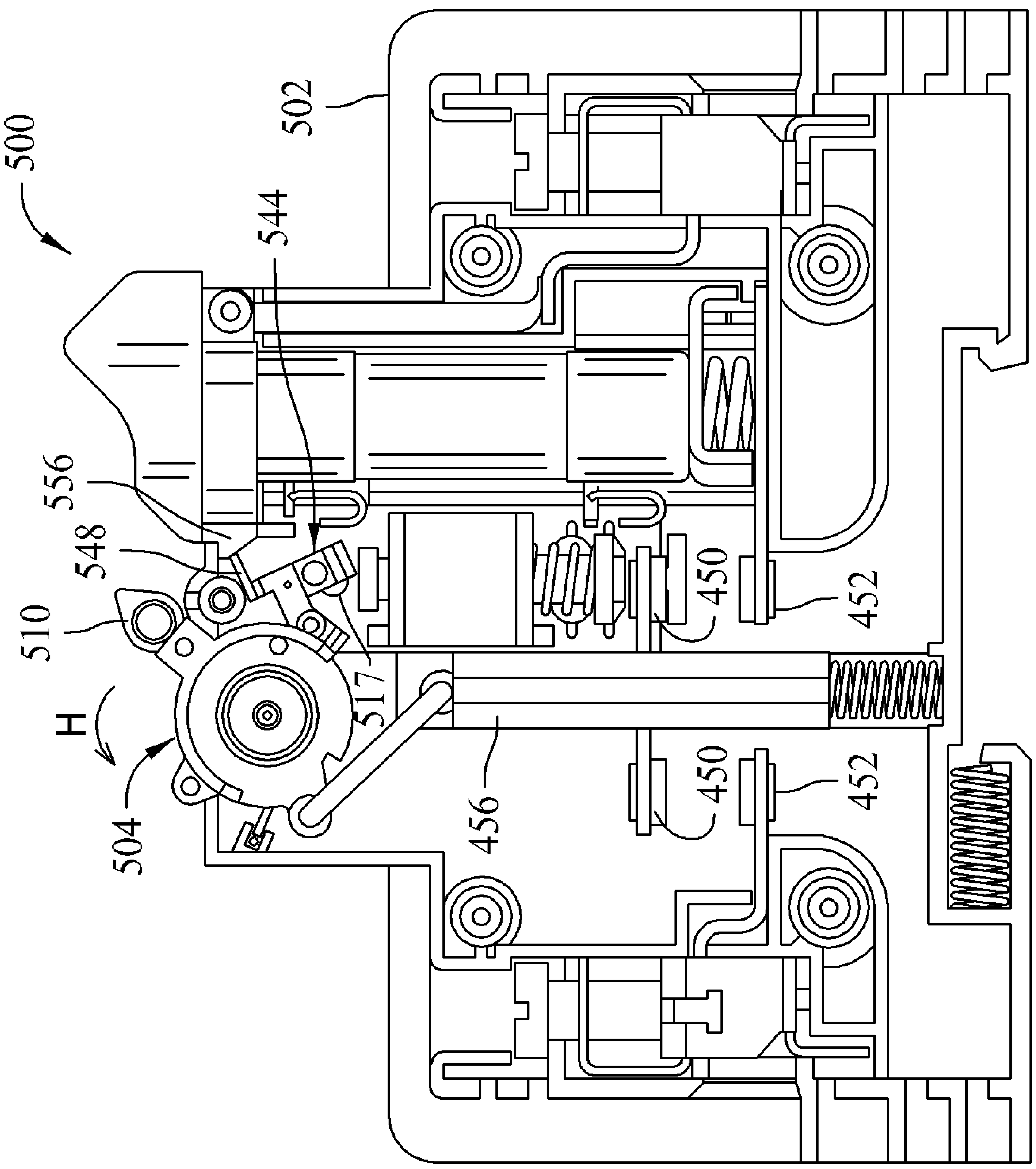
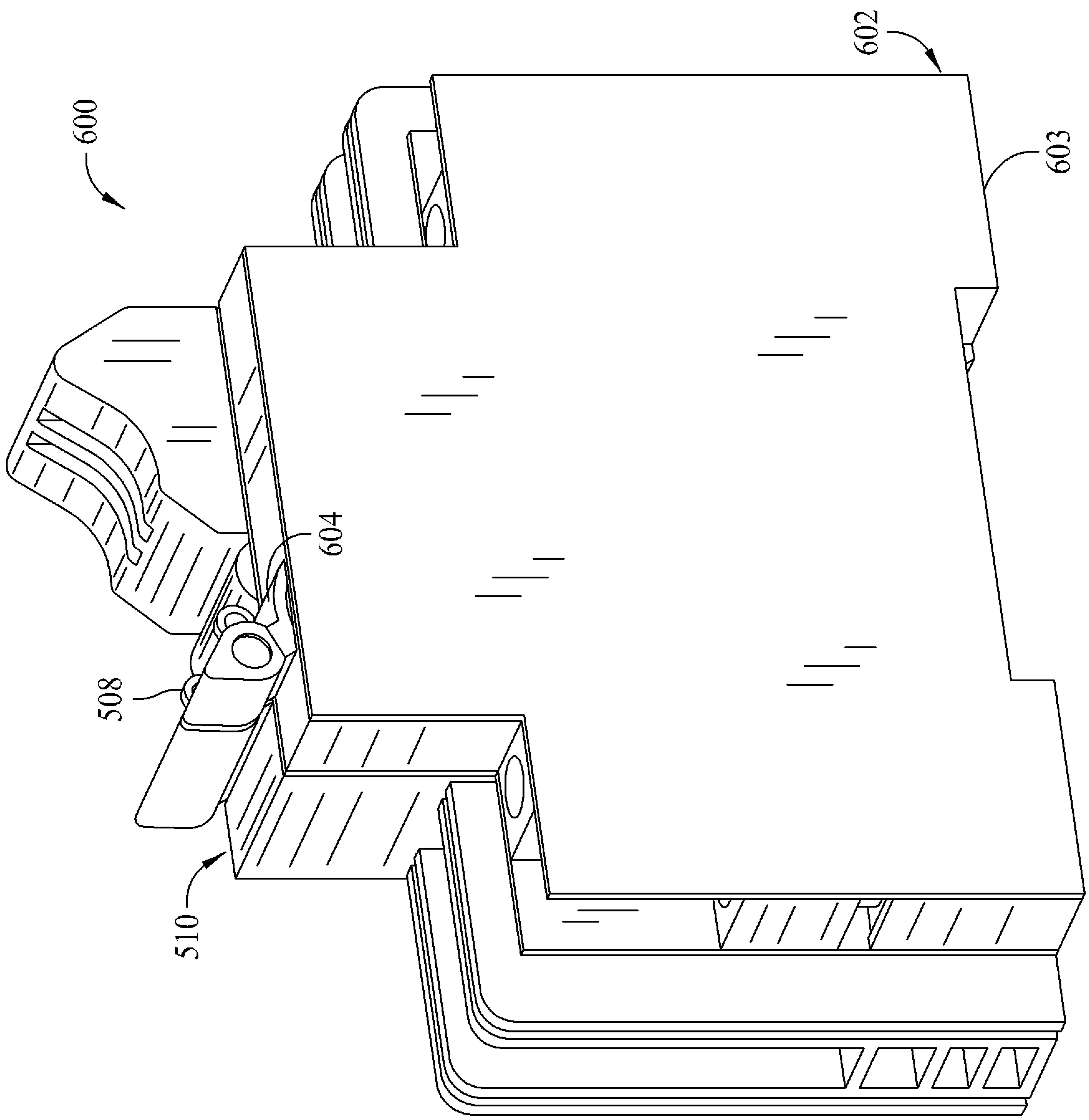


FIG. 22

FIG. 23



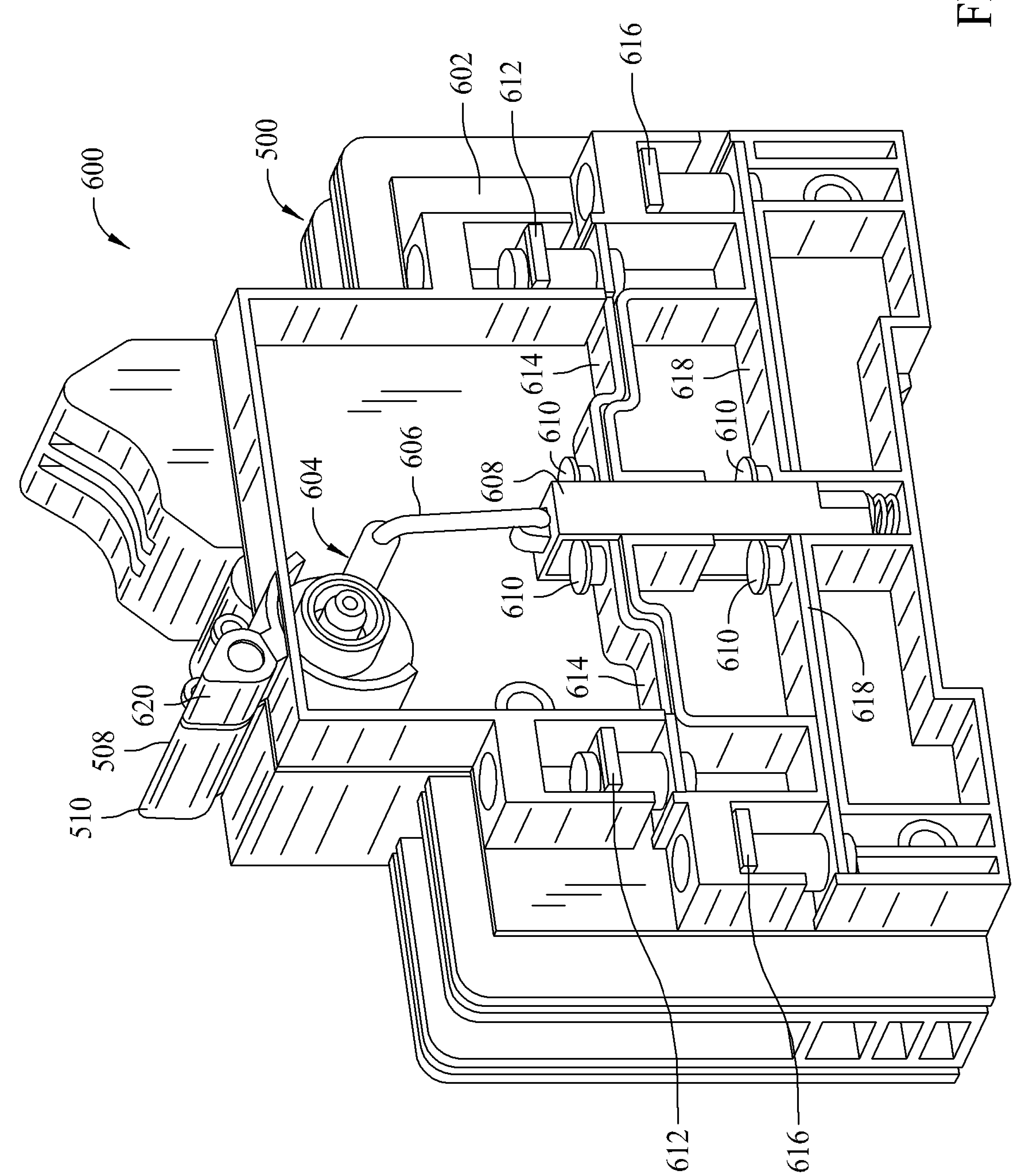


FIG. 24

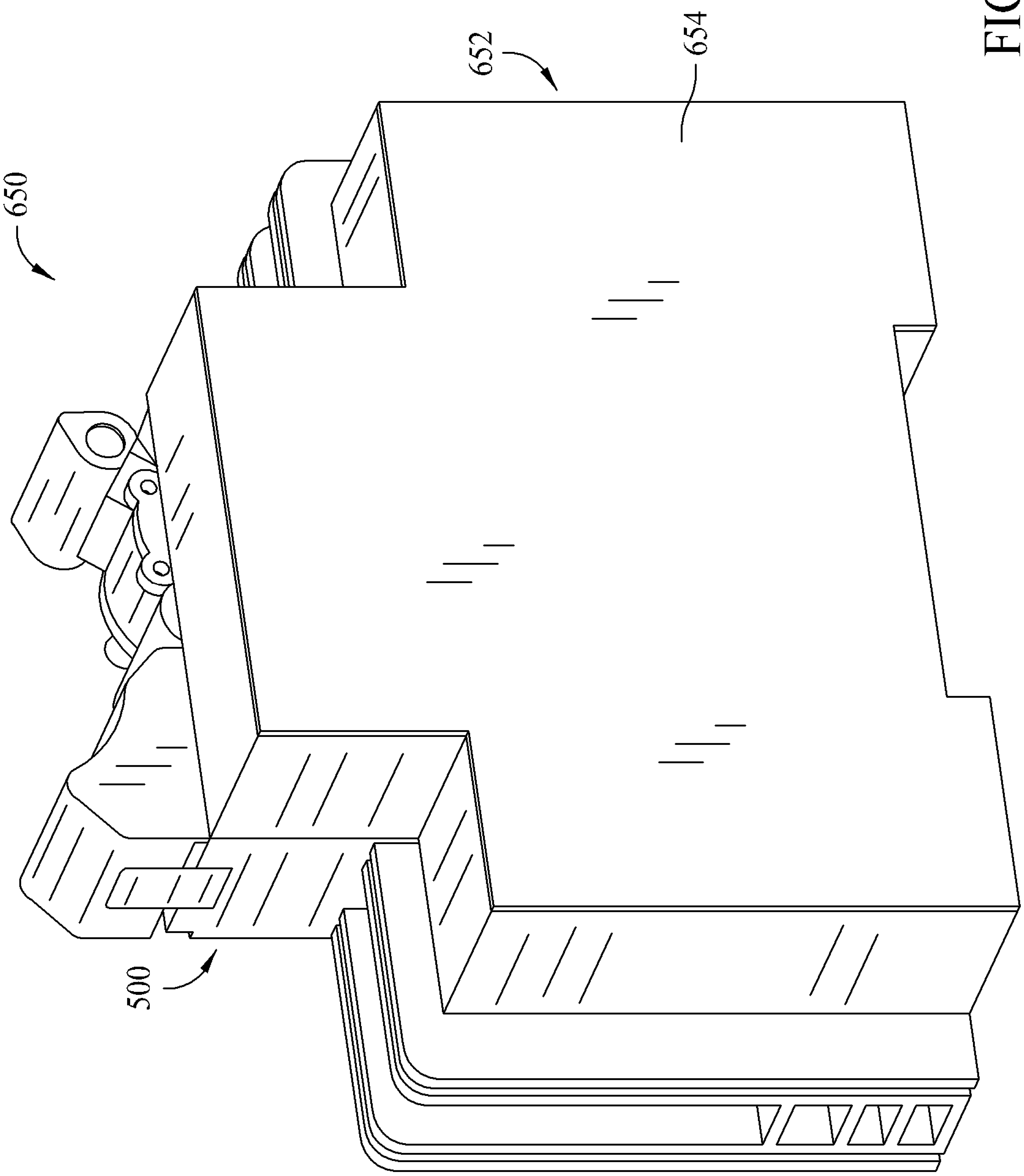


FIG. 25

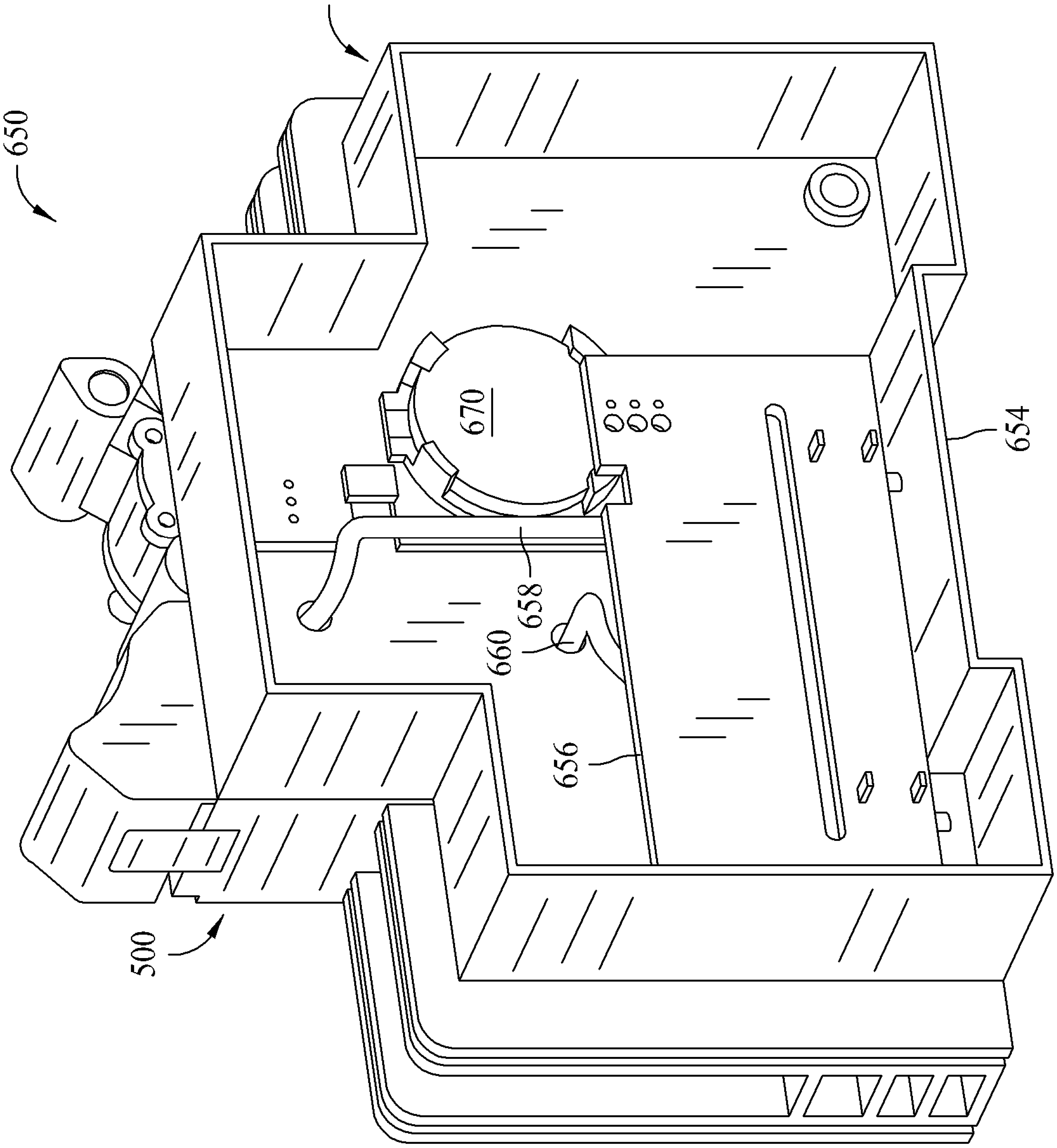
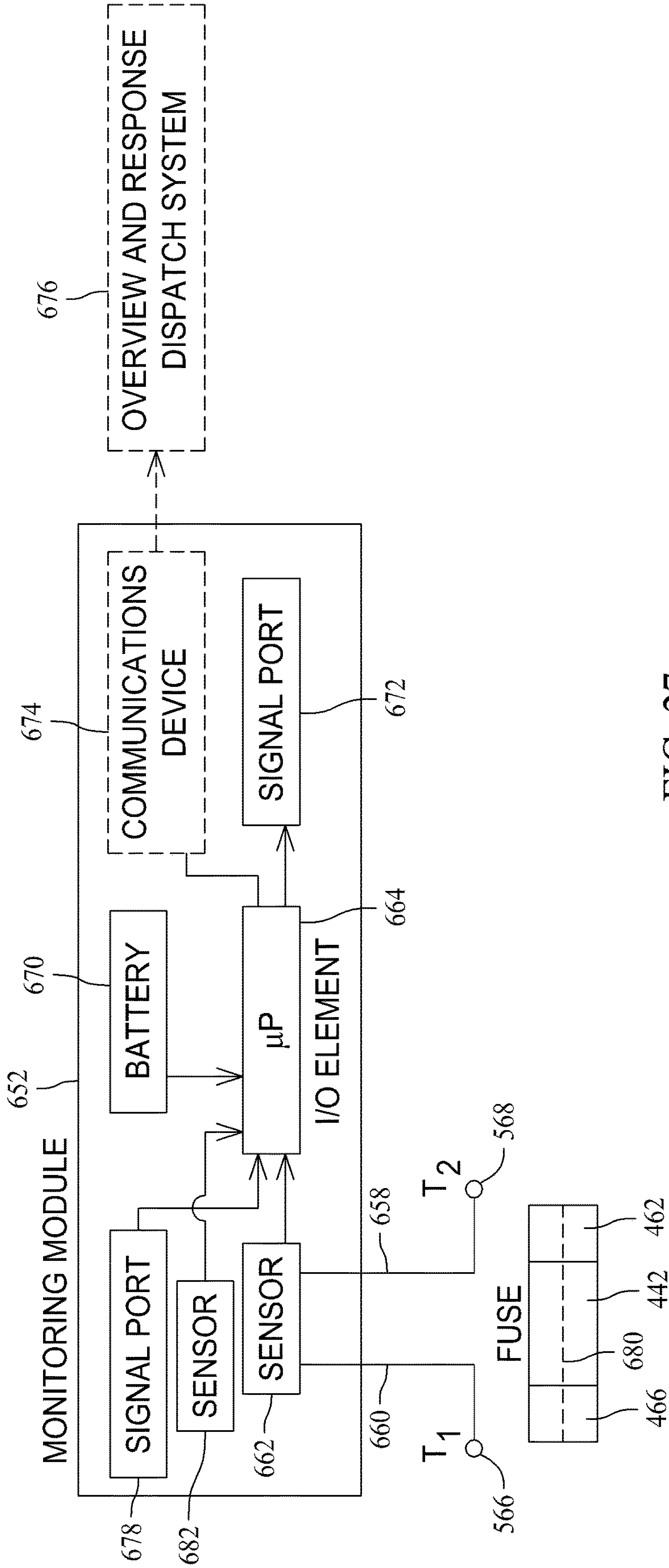


FIG. 26



OVERVIEW AND RESPONSE DISPATCH SYSTEM
676
MONITORING MODULE
652
COMMUNICATIONS DEVICE
674
SIGNAL PORT
672
BATTERY
670
μP
I/O ELEMENT
664
SIGNAL PORT
678
SENSOR
682
SENSOR
662
658
660
T_2
568
T_1
566
FUSE
462
442
680
466

FIG. 27

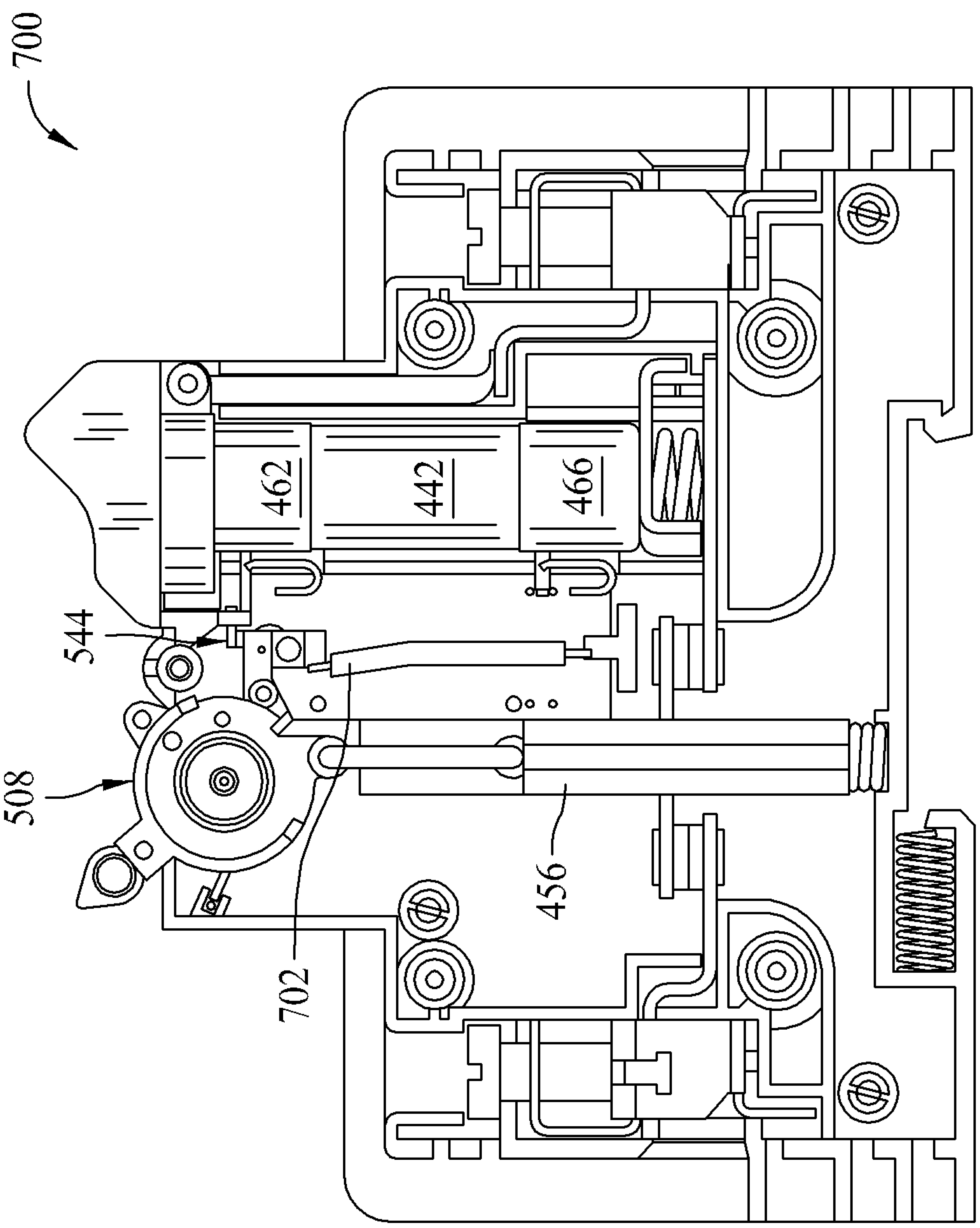


FIG. 28

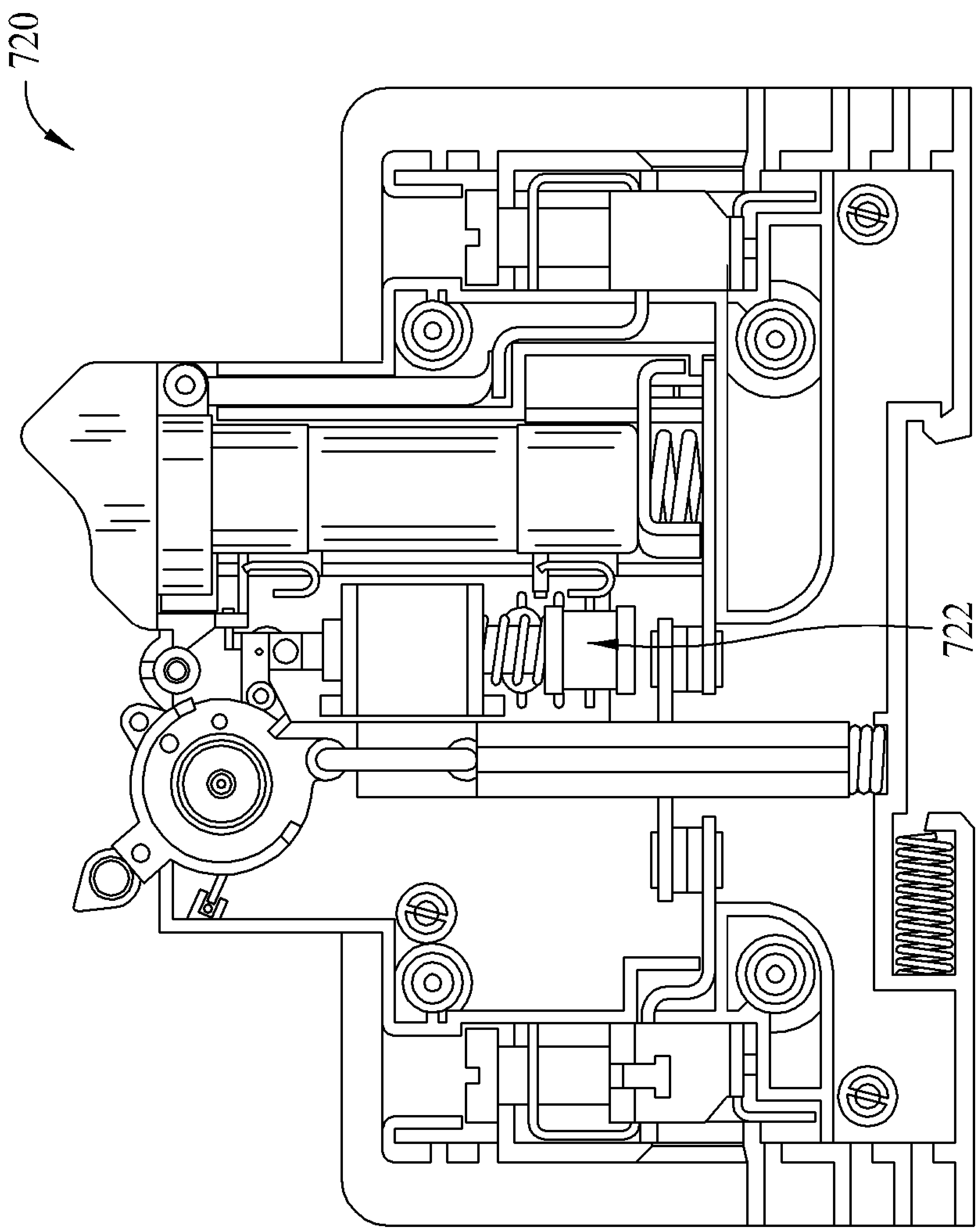
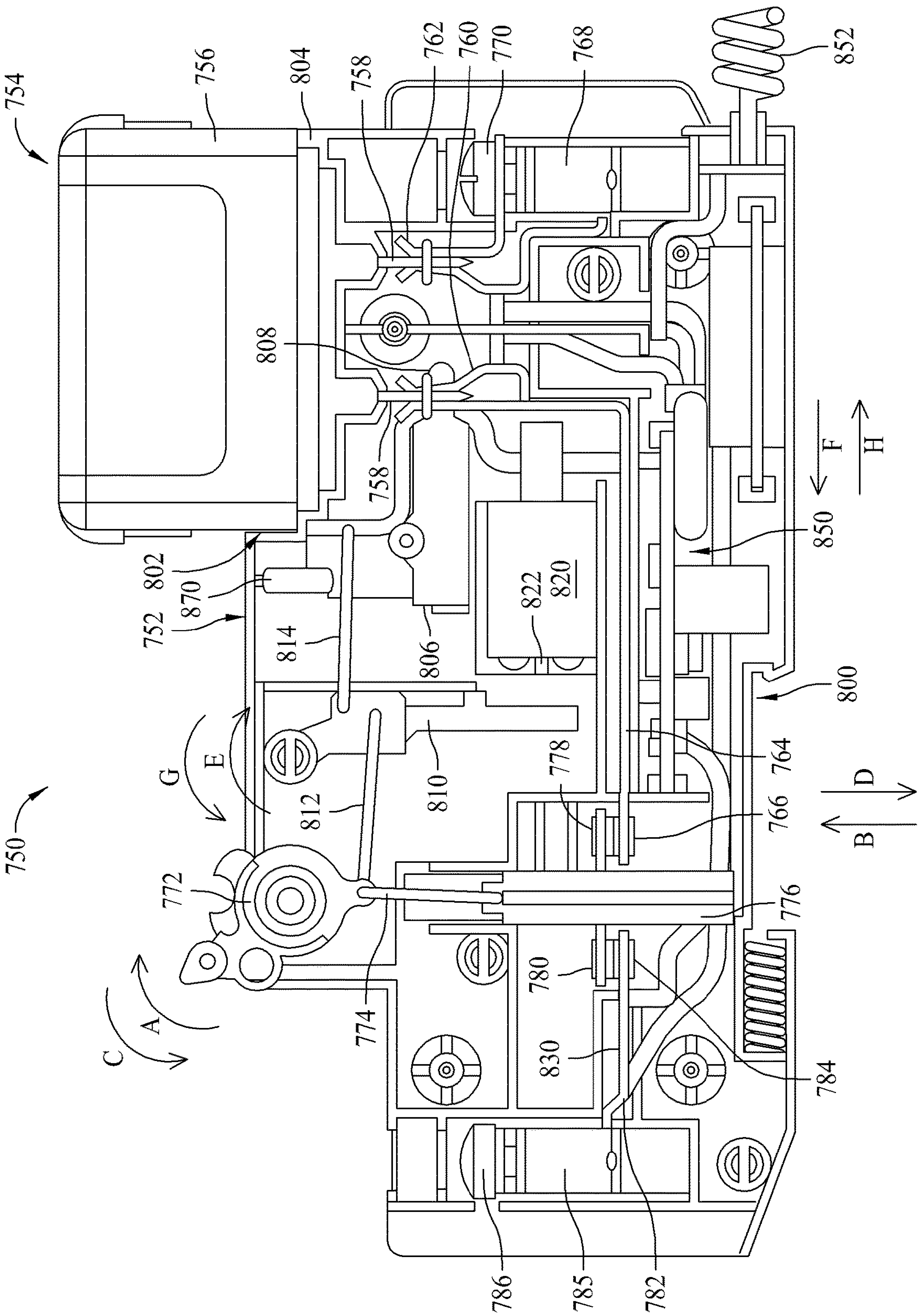


FIG. 29


754
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804
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870
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814
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FIG. 30

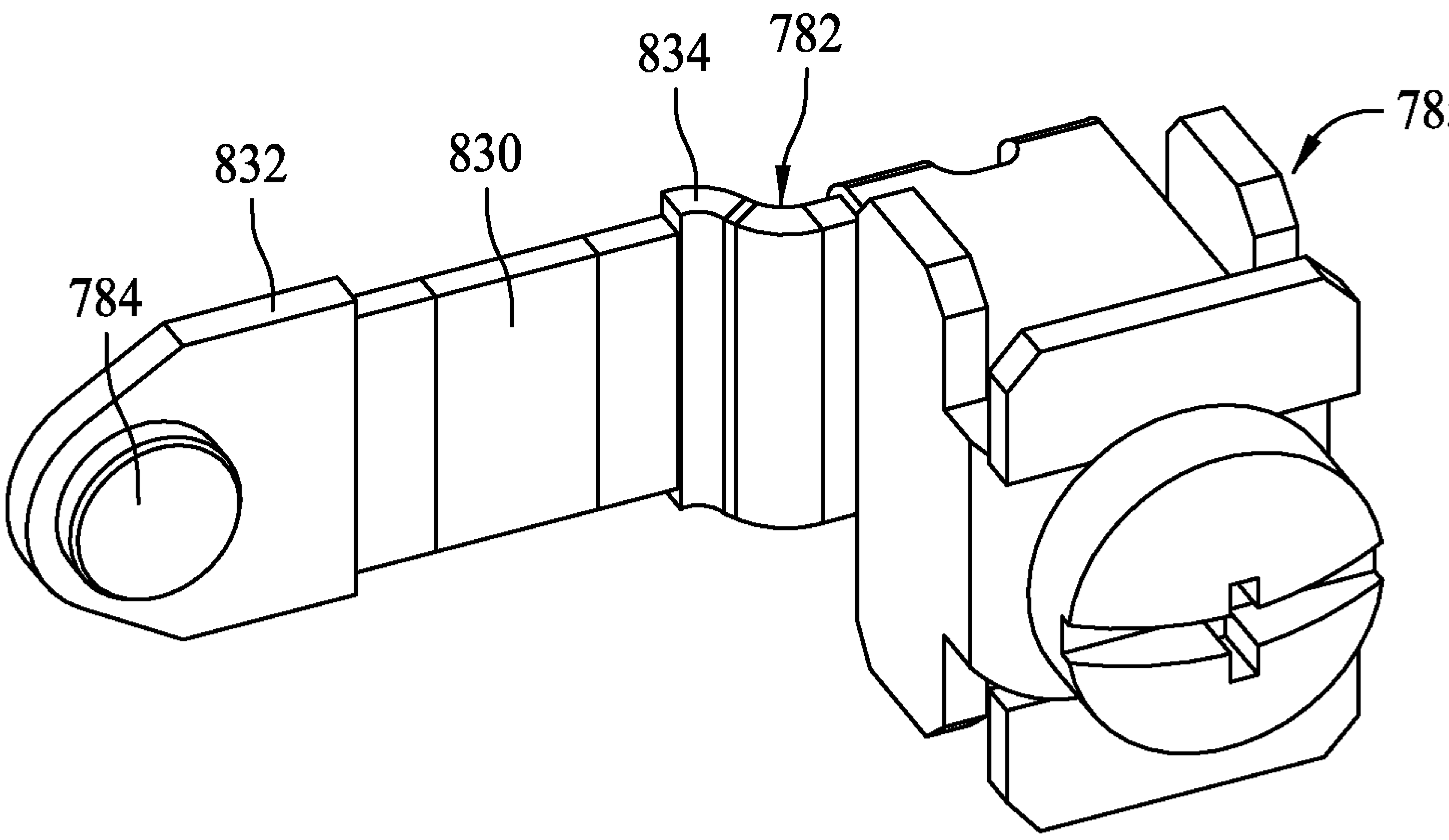

FIG. 31

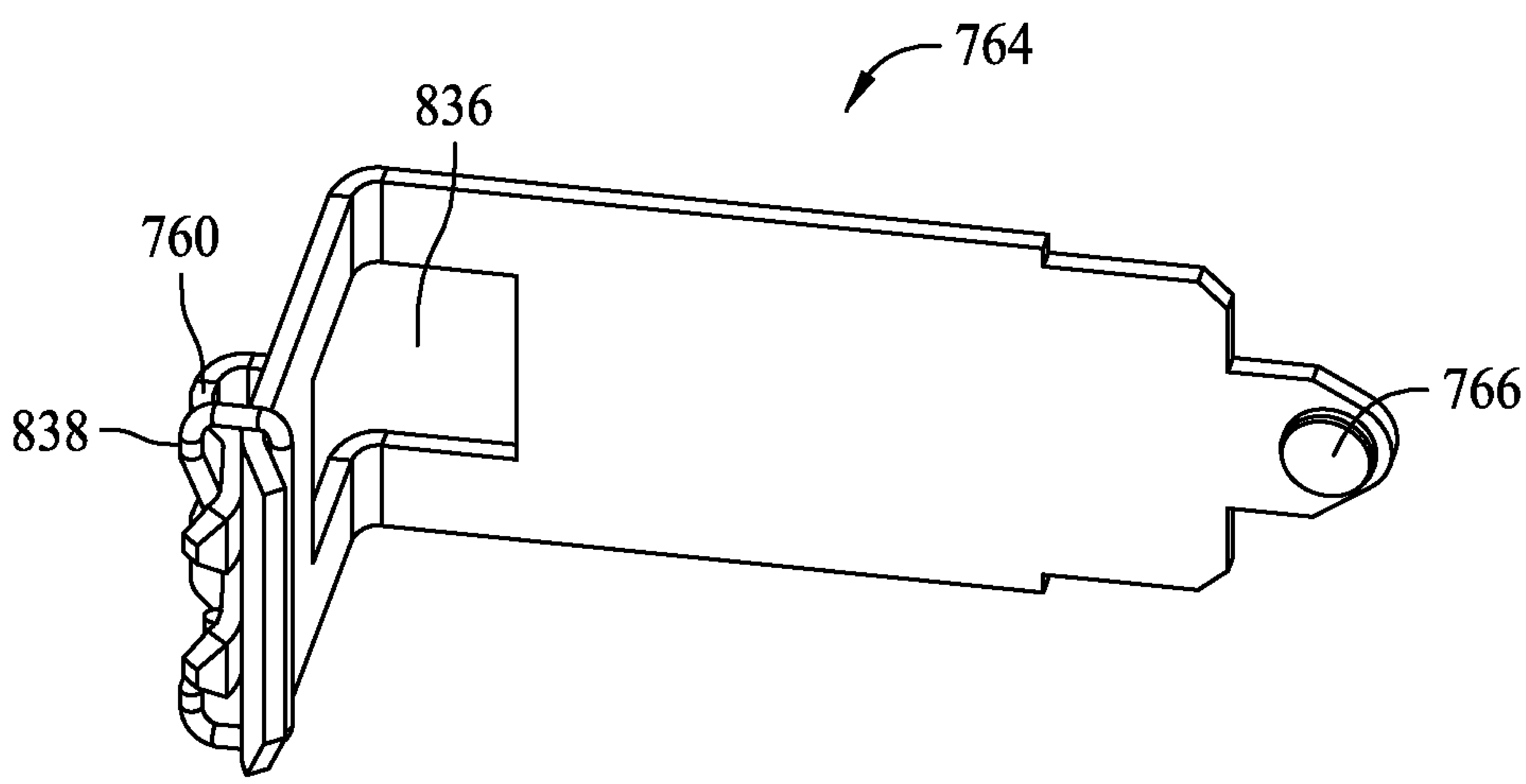

FIG. 32

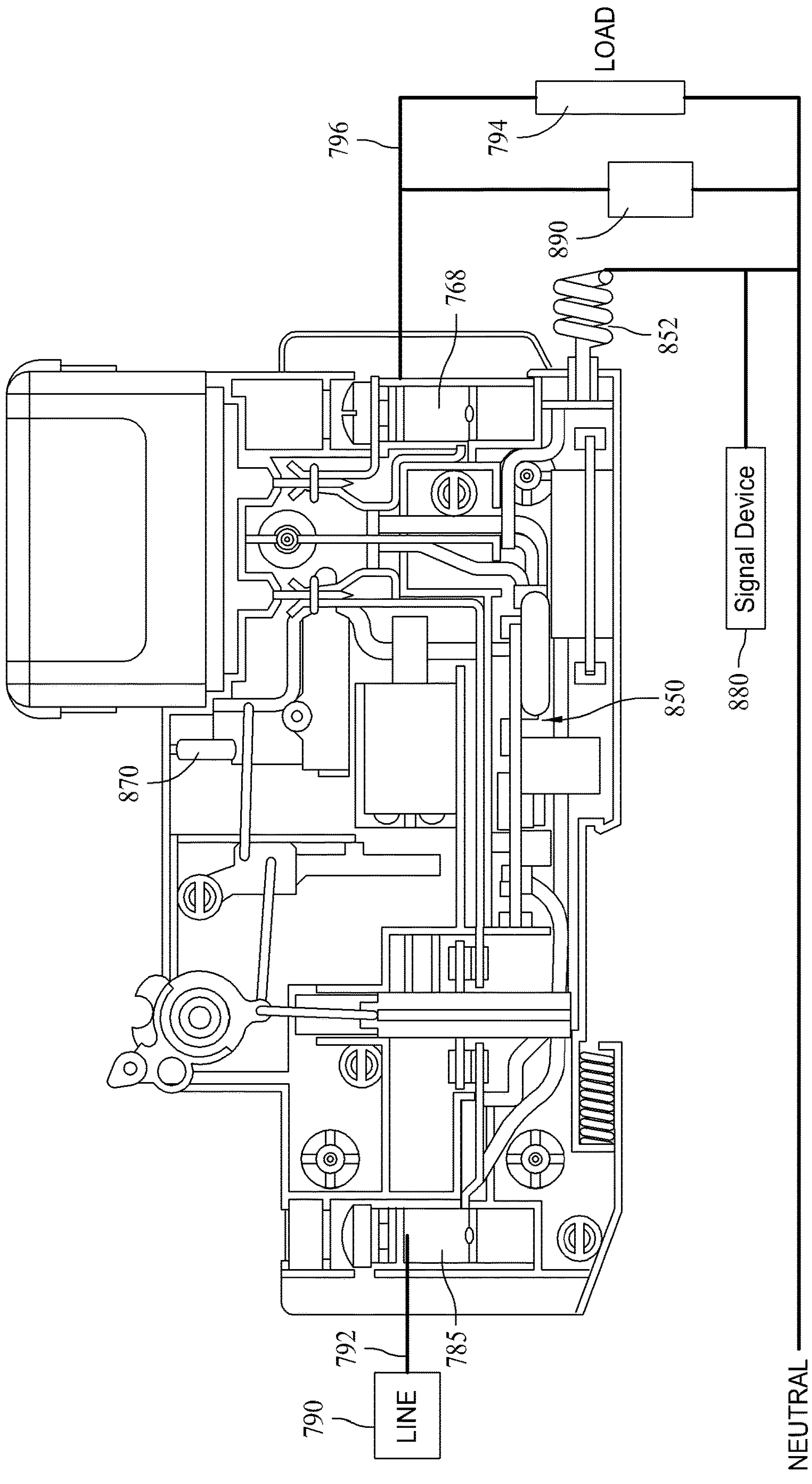
LOAD
796
794
890
768
852
Signal Device
880
850
870
NEUTRAL
785
792
790
LINE

FIG. 33

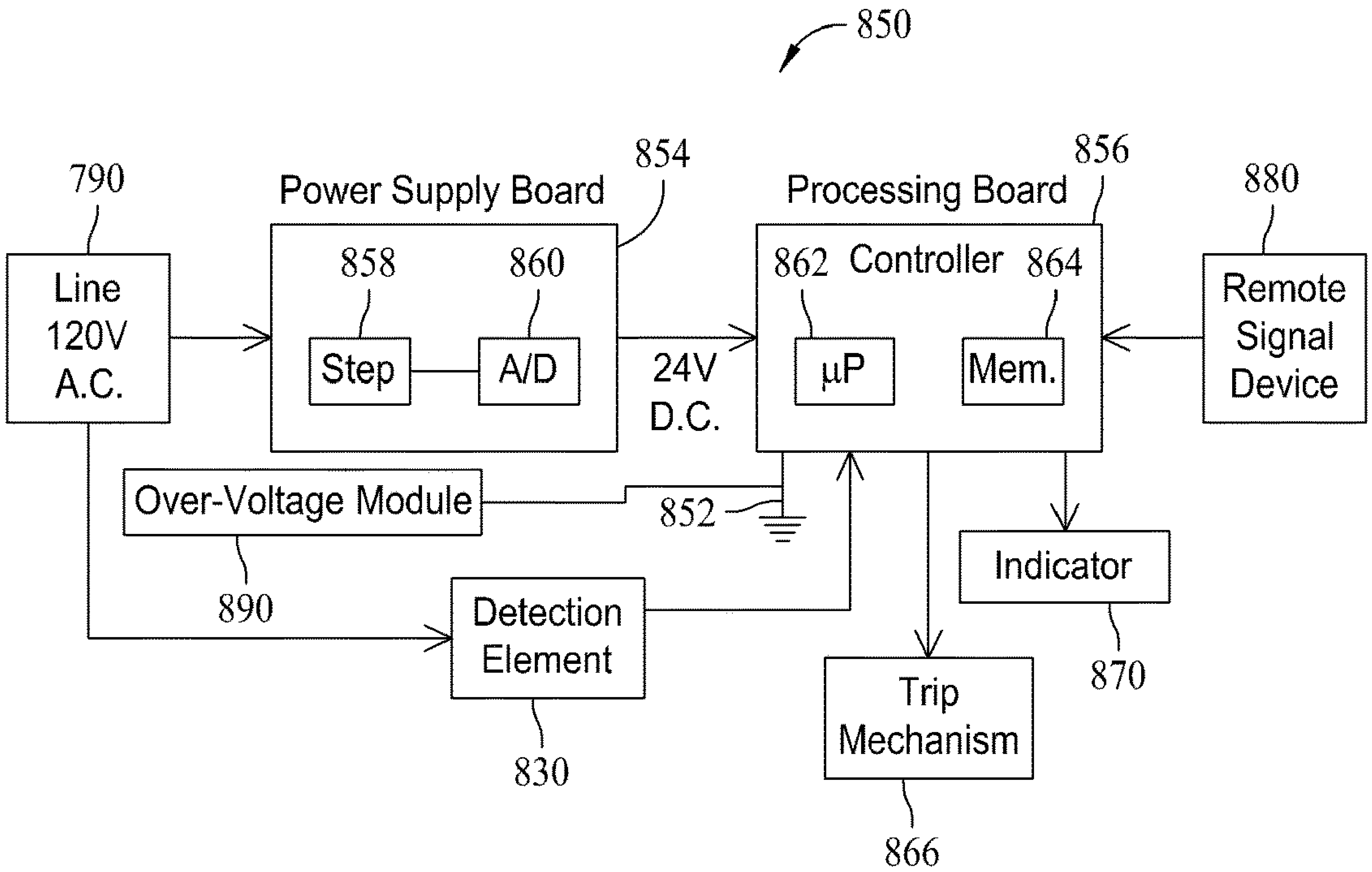
850
790
Line
120V
A.C.
Power Supply Board
854
858
860
Step
A/D
24V
D.C.
Processing Board
856
862
Controller
864
μP
Mem.
880
Remote
Signal
Device
Over-Voltage Module
852
890
Detection
Element
830
Indicator
870
Trip
Mechanism
866

FIG. 34

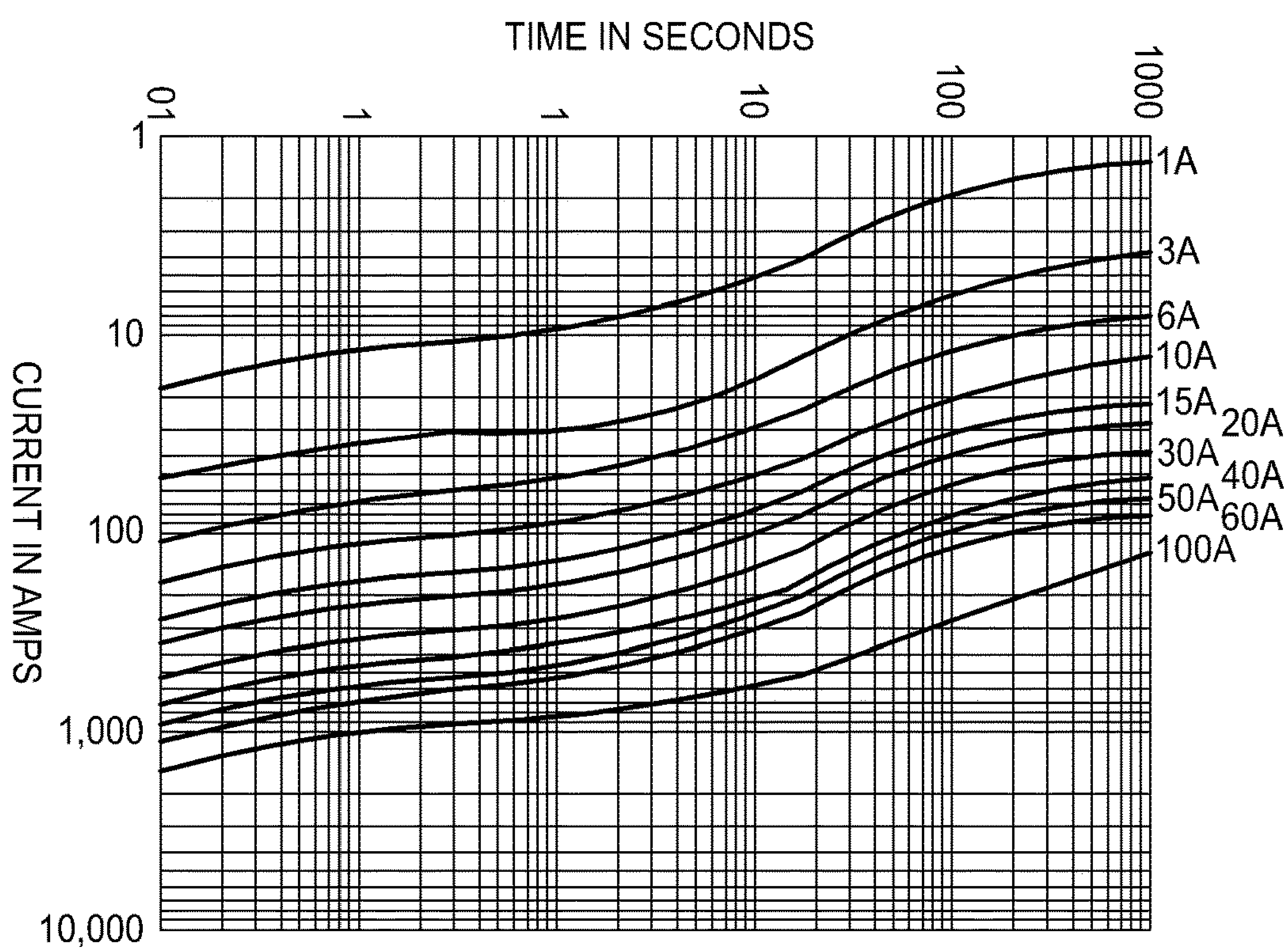
TIME IN SECONDS
10
100
1000
CURRENT IN AMPS
1
10
100
1,000
10,000
1A
3A
6A
10A
15A
20A
30A
40A
50A
60A
100A

FIG. 35

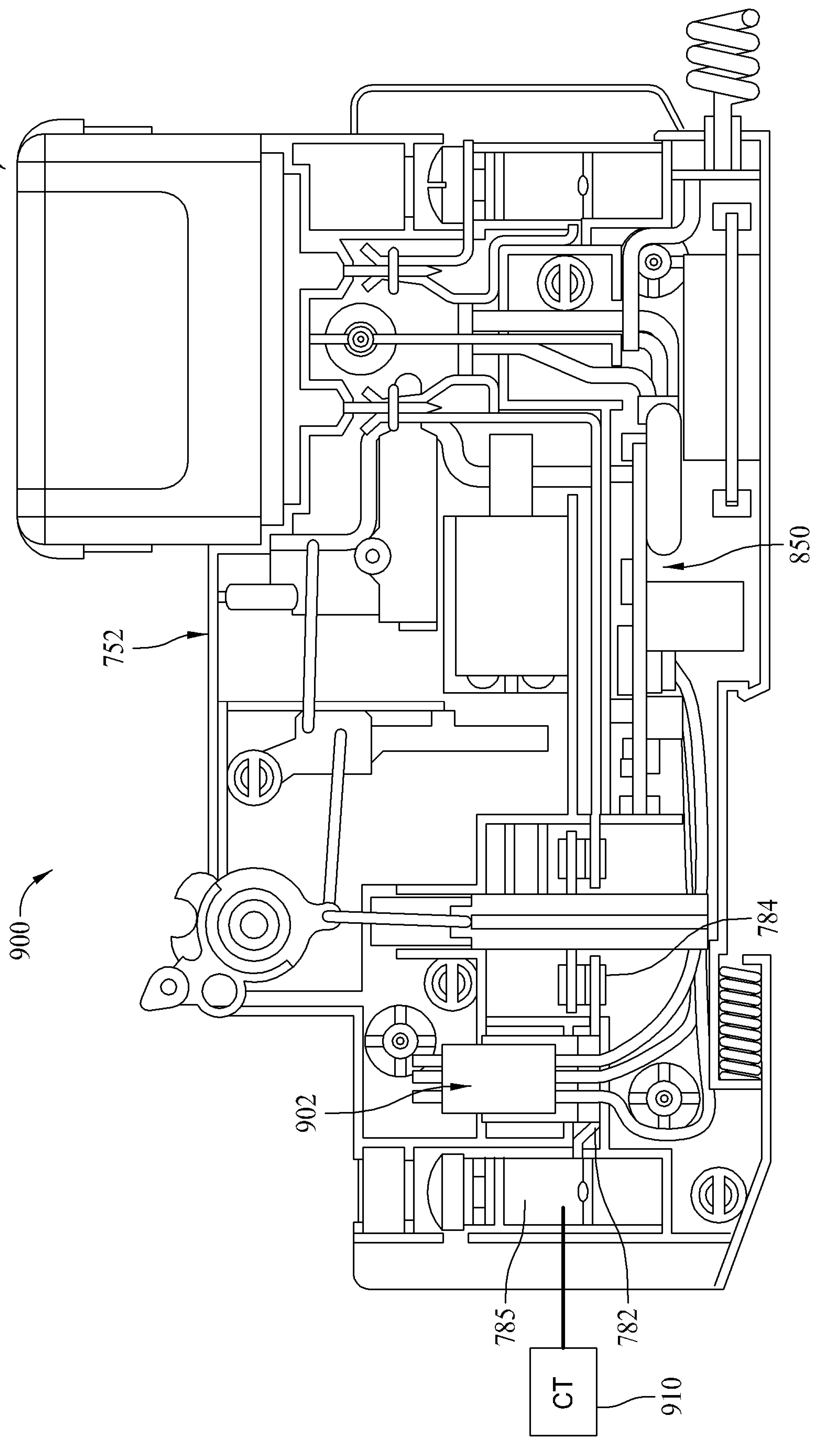

FIG. 36

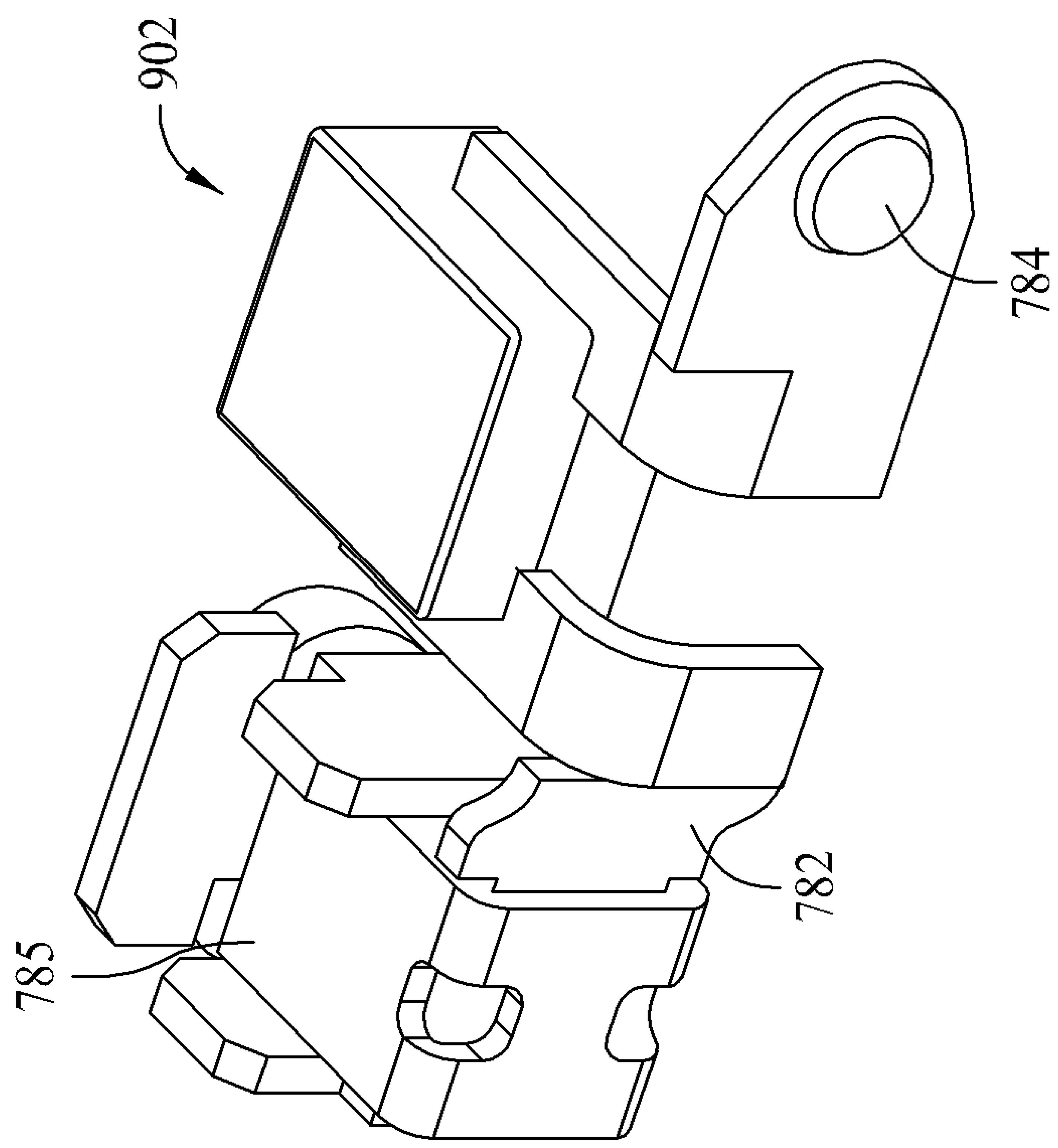

FIG. 37

ELECTRONICALLY CONTROLLED FUSIBLE SWITCHING DISCONNECT MODULES AND DEVICES

CROSS REFERENCE TO RELATED APPLICATIONS

This application relates to subject matter disclosed in U.S. patent application Ser. No. 13/008,950 filed Jan. 19, 2011 and entitled Fusible Switching Disconnect Modules and Devices With In-Line Current Detection; U.S. patent application Ser. No. 13/008,988 filed Jan. 19, 2011 and entitled Fusible Switching Disconnect Modules and Devices with Tripping Coil; and U.S. patent application Ser. No. 13/009,012 filed Jan. 19, 2011 entitled Fusible Switching Disconnect Modules and Devices with Multi-Functional Trip Mechanism and now issued U.S. Pat. No. 8,614,618.

BACKGROUND OF THE INVENTION

This invention relates generally to fuses, and, more particularly, to fused disconnect switches.

Fuses are widely used as overcurrent protection devices to prevent costly damage to electrical circuits. Fuse terminals typically form an electrical connection between an electrical power source and an electrical component or a combination of components arranged in an electrical circuit. One or more fusible links or elements, or a fuse element assembly, is connected between the fuse terminals, so that when electrical current through the fuse exceeds a predetermined limit, the fusible elements melt and opens one or more circuits through the fuse to prevent electrical component damage.

In some applications, fuses are employed not only to provide fused electrical connections but also for connection and disconnection, or switching, purposes to complete or break an electrical connection or connections. As such, an electrical circuit is completed or broken through conductive portions of the fuse, thereby energizing or de-energizing the associated circuitry. Typically, the fuse is housed in a fuse holder having terminals that are electrically coupled to desired circuitry. When conductive portions of the fuse, such as fuse blades, terminals, or ferrules, are engaged to the fuse holder terminals, an electrical circuit is completed through the fuse, and when conductive portions of the fuse are disengaged from the fuse holder terminals, the electrical circuit through the fuse is broken. Therefore, by inserting and removing the fuse to and from the fuse holder terminals, a fused disconnect switch is realized.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an exemplary fusible switching disconnect device.

FIG. **2** is a side elevational view of a portion of the fusible switching disconnect device shown in FIG. **1** in a closed position.

FIG. **3** is a side elevational view of a portion of the fusible switching disconnect device shown in FIG. **1** in an open position.

FIG. **4** is a side elevational view of a second embodiment of a fusible switching disconnect device.

FIG. **5** is a perspective view of a third embodiment of a fusible switching disconnect device.

FIG. **6** is a perspective view of a fourth embodiment of a fusible switching disconnect device.

FIG. **7** is a side elevational view of the fusible switching disconnect device shown in FIG. **7**.

FIG. **8** is a perspective view of a fifth embodiment of a fusible switching disconnect device.

FIG. **9** is a perspective view of a portion of the fusible switching disconnect device shown in FIG. **8**.

FIG. **10** is a perspective view of a sixth embodiment of a fusible switching disconnect device.

FIG. **11** is a perspective view of a seventh embodiment of a fusible switching disconnect device.

FIG. **12** is a perspective view of an eighth embodiment of a fusible switching disconnect device in a closed position.

FIG. **13** is a side elevational view of a portion of the fusible switching disconnect device shown in FIG. **12**.

FIG. **14** is a perspective view of the fusible switching disconnect device shown in FIGS. **12** and **13** in an opened position.

FIG. **15** is a side elevational view of a portion of the fusible switching disconnect device shown in FIG. **14**.

FIG. **16** is a perspective view of a ganged arrangement of fusible switching devices shown in FIGS. **12-15**.

FIG. **17** is a perspective view of a ninth embodiment of a fusible switching disconnect device in a closed position.

FIG. **18** is a side elevational view of a portion of the fusible switching disconnect device shown in FIG. **17**.

FIG. **19** is a side elevational view of the fusible switching disconnect device shown in FIG. **17** in an opened position.

FIG. **20** is a perspective view of the fusible switching disconnect device shown in FIG. **19**.

FIG. **21** is a perspective view of the fusible switching disconnect device shown in FIG. **20** in a closed position.

FIG. **22** is a side elevational view of the fusible switching device shown in FIG. **21**.

FIG. **23** is a perspective view of a tenth embodiment of a fusible switching disconnect device.

FIG. **24** is a perspective view of a portion of the fusible switching disconnect device shown in FIG. **23**.

FIG. **25** is a perspective view of an eleventh embodiment of a fusible switching disconnect device.

FIG. **26** is a perspective view of a portion of the fusible switching disconnect device shown in FIG. **25**.

FIG. **27** is a schematic diagram of the fusible switching disconnect device shown in FIG. **26**.

FIG. **28** is a side elevational view of a portion of a twelfth embodiment of a fusible switching disconnect device.

FIG. **29** is a side elevational view of a portion of a thirteenth embodiment of a fusible switching disconnect device.

FIG. **30** is a side elevational view of a portion of a fourteenth embodiment of a fusible switching disconnect device.

FIG. **31** illustrates a first terminal for the device shown in FIG. **30** including a switch contact.

FIG. **32** illustrates a second terminal for the device shown in FIG. **30** including another switch contact.

FIG. **33** illustrates a schematic of the device shown in FIG. **30** connected to electrical circuitry.

FIG. **34** is a block diagram of power supply and control circuitry for the device shown in FIG. **30**.

FIG. **35** is an exemplary time-current curve for exemplary fuses useable with the device shown in FIG. **35**.

FIG. **36** is a side elevational view of a portion of a fifteenth embodiment of a fusible switching disconnect device.

FIG. **37** illustrates a first terminal for the device shown in FIG. **36**.

DETAILED DESCRIPTION OF THE INVENTION

Known fused disconnects are subject to a number of problems in use. For example, any attempt to remove the fuse while the fuses are energized and under load may result in hazardous conditions because dangerous arcing may occur between the fuses and the fuse holder terminals. Some fuseholders designed to accommodate, for example, UL (Underwriters Laboratories) Class CC fuses and IEC (International Electrotechnical Commission) 10×38 fuses that are commonly used in industrial control devices include permanently mounted auxiliary contacts and associated rotary cams and switches to provide early-break and late-make voltage and current connections through the fuses when the fuses are pulled from fuse clips in a protective housing. One or more fuses may be pulled from the fuse clips, for example, by removing a drawer from the protective housing. Early-break and late-make connections are commonly employed, for example, in motor control applications. While early-break and late-make connections may increase the safety of such devices to users when installing and removing fuses, such features increase costs, complicate assembly of the fuseholder, and are undesirable for switching purposes.

Structurally, the early-break and late-make connections can be intricate and may not withstand repeated use for switching purposes. In addition, when opening and closing the drawer to disconnect or reconnect circuitry, the drawer may be inadvertently left in a partly opened or partly closed position. In either case, the fuses in the drawer may not be completely engaged to the fuse terminals, thereby compromising the electrical connection and rendering the fuseholder susceptible to unintended opening and closing of the circuit. Especially in environments subject to vibration, the fuses may be jarred loose from the clips. Still further, a partially opened drawer protruding from the fuseholder may interfere with workspace around the fuseholder. Workers may unintentionally bump into the opened drawers, and perhaps unintentionally close the drawer and re-energize the circuit.

Additionally, in certain systems, such as industrial control devices, electrical equipment has become standardized in size and shape, and because known fused disconnect switches tend to vary in size and shape from the standard norms, they are not necessarily compatible with power distribution panels utilized with such equipment. For at least the above reasons, use of fused disconnect switches have not completely met the needs of certain end applications.

FIG. **1** is a perspective view of an exemplary fusible switching disconnect device **100** that overcomes the aforementioned difficulties. The fusible switching disconnect device **100** may be conveniently switched on and off in a convenient and safe manner without interfering with workspace around the device **100**. The disconnect device **100** may reliably switch a circuit on and off in a cost effective manner and may be used with standardized equipment in, for example, industrial control applications. Further, the disconnect device **100** may be provided with various mounting and connection options for versatility in the field. Various embodiments will be described below to demonstrate the versatility of the disconnect device, and it is contemplated that the disconnect device **100** may be beneficial in a variety of electrical circuits and applications. The embodiments set forth below are therefore provided for illustrative purposes only, and the invention is not intended to be limited to any specific embodiment or to any specific application.

In the illustrative embodiment of FIG. **1**, the disconnect device **100** may be a two pole device formed from two separate disconnect modules **102**. Each module **102** may include an insulative housing **104**, a fuse **106** loaded into the housing **104**, a fuse cover or cap **108** attaching the fuse to the housing **104**, and a switch actuator **110**. The modules **102** are single pole modules, and the modules **102** may be coupled or ganged together to form the two pole disconnect device **100**. It is contemplated, however, that a multi-pole device could be formed in a single housing rather than in the modular fashion of the exemplary embodiment shown in FIG. **1**.

The housing **104** may be fabricated from an insulative or nonconductive material, such as plastic, according to known methods and techniques, including but not limited to injection molding techniques. In an exemplary embodiment, the housing **104** is formed into a generally rectangular size and shape which is complementary to and compatible with DIN and IEC standards applicable to standardized electrical equipment. In particular, for example, each housing **104** has lower edge **112**, opposite side edges **114**, side panels **116** extending between the side edges **114**, and an upper surface **118** extending between the side edges **114** and the side panels **116**. The lower edge **112** has a length L and the side edges **114** have a thickness T, such as 17.5 mm in one embodiment, and the length L and thickness T define an area or footprint on the lower edge **112** of the housing **104**. The footprint allows the lower edge **112** to be inserted into a standardized opening having a complementary shape and dimension. Additionally, the side edges **114** of the housing **104** have a height H in accordance with known standards, and the side edges **114** include slots **120** extending therethrough for ventilating the housing **104**. The upper surface **118** of the housing **104** may be contoured to include a raised central portion **122** and recessed end portions **124** extending to the side edges **114** of the housing **104**.

The fuse **106** of each module **102** may be loaded vertically in the housing **104** through an opening in the upper surface **118** of the housing **104**, and the fuse **106** may extend partly through the raised central portion **122** of the upper surface **118**. The fuse cover **108** extends over the exposed portion of the fuse **106** extending from the housing **104**, and the cover **108** secures the fuse **106** to the housing **104** in each module **102**. In an exemplary embodiment, the cover **108** may be fabricated from a non-conductive material, such as plastic, and may be formed with a generally flat or planar end section **126** and elongated fingers **128** extending between the upper surface **118** of the raised central portion **122** of the housing **104** and the end of the fuse **106**. Openings are provided in between adjacent fingers **128** to ventilate the end of the fuse **106**.

In an exemplary embodiment, the cover **108** further includes rim sections **130** joining the fingers **128** opposite the end section **126** of the cover **108**, and the rim sections **130** secure the cover **108** to the housing **104**. In an exemplary embodiment, the rim sections **130** cooperate with grooves in the housing **104** such that the cover **108** may rotate a predetermined amount, such as 25 degrees, between a locked position and a release position. That is, once the fuse **106** is inserted into the housing **104**, the fuse cover **108** may be installed over the end of the fuse **106** into the groove of the housing **104**, and the cover **108** may be rotated 25 degrees to the locked position wherein the cover **108** will frustrate removal of the fuse **106** from the housing **104**. The groove may also be ramped or inclined such that the cover **108** applies a slight downward force on the fuse **106** as the cover **108** is installed. To remove the fuse **106**, the cover **108** may be rotated from the locked position to the open position wherein both the cover **108** and the fuse **106** may be removed from the housing **104**.

The switch actuator **110** may be located in an aperture **132** of the raised upper surface **122** of the housing **104**, and the switch actuator **110** may partly extend through the raised upper surface **122** of the housing **104**. The switch actuator **100** may be rotatably mounted to the housing **104** on a shaft or axle **134** within the housing **104**, and the switch actuator **110** may include a lever, handle or bar **136** extending radially from the actuator **110**. By moving the lever **136** from a first edge **138** to a second edge **140** of the aperture **132**, the shaft **134** rotates to an open or switch position and electrically disconnects the fuse **106** in each module **102** as explained below. When the lever **136** is moved from the second edge **140** to the first edge **138**, the shaft **134** rotates back to the closed position illustrated in FIG. **1** and electrically connects the fuse **106**.

A line side terminal element may **142** extend from the lower edge **112** of the housing **104** in each module **102** for establishing line and load connections to circuitry. As shown in FIG. **1**, the line side terminal element **142** is a bus bar clip configured or adapted to connect to a line input bus, although it is contemplated that other line side terminal elements could be employed in alternative embodiments. A panel mount clip **144** also extends from the lower edge **112** of the housing **104** to facilitate mounting of the disconnect device **100** on a panel.

FIG. **2** is a side elevational view of one of the disconnect modules **102** shown in FIG. **1** with the side panel **116** removed. The fuse **106** may be seen situated in a compartment **150** inside the housing **104**. In an exemplary embodiment, the fuse **106** may be a cylindrical cartridge fuse including an insulative cylindrical body **152**, conductive ferrules or end caps **154** coupled to each end of the body **152**, and a fuse element or fuse element assembly extending within the body **152** and electrically connected to the end caps **154**. In exemplary embodiments, the fuse **106** may be a UL Class CC fuse, a UL supplemental fuse, or an IEC 10×38 fuses which are commonly used in industrial control applications. These and other types of cartridge fuses suitable for use in the module **102** are commercially available from Cooper Bussmann of St. Louis, Mo. It is understood that other types of fuses may also be used in the module **102** as desired.

A lower conductive fuse terminal **156** may be located in a bottom portion of the fuse compartment **150** and may be U-shaped in one embodiment. One of the end caps **154** of the fuse **106** rests upon an upper leg **158** of the lower terminal **156**, and the other end cap **154** of the fuse **106** is coupled to an upper terminal **160** located in the housing **104** adjacent the fuse compartment **150**. The upper terminal **160** is, in turn, connected to a load side terminal **162** to accept a load side connection to the disconnect module **102** in a known manner. The load side terminal **162** in one embodiment is a known saddle screw terminal, although it is appreciated that other types of terminals could be employed for load side connections to the module **102**. Additionally, the lower fuse terminal **156** may include fuse rejection features in a further embodiment which prevent installation of incorrect fuse types into the module **102**.

The switch actuator **110** may be located in an actuator compartment **164** within the housing **104** and may include the shaft **134**, a rounded body **166** extending generally radially from the shaft **134**, the lever **136** extending from the body **166**, and an actuator link **168** coupled to the actuator body **166**. The actuator link **168** may be connected to a spring loaded contact assembly **170** including first and second movable or switchable contacts **172** and **174** coupled to a sliding bar **176**. In the closed position illustrated in FIG. **2**, the switchable contacts **172** and **174** are mechanically and electrically engaged to stationary contacts **178** and **180** mounted in the housing **104**. One of the stationary contacts **178** may be mounted to an end of the terminal element **142**, and the other of the stationary contacts **180** may be mounted to an end of the lower fuse terminal **156**. When the switchable contacts **172** and **174** are engaged to the stationary contacts **178** and **180**, a circuit is path completed through the fuse **106** from the line terminal **142** and the lower fuse terminal **156** to the upper fuse terminal **160** and the load terminal **162**.

While in an exemplary embodiment the stationary contact **178** is mounted to a terminal **142** having a bus bar clip, another terminal element, such as a known box lug or clamp terminal could be provided in a compartment **182** in the housing **104** in lieu of the bus bar clip. Thus, the module **102** may be used with a hard-wired connection to line-side circuitry instead of a line input bus. Thus, the module **102** is readily convertible to different mounting options in the field.

When the switch actuator **110** is rotated about the shaft **134** in the direction of arrow A, the siding bar **176** may be moved linearly upward in the direction of arrow B to disengage the switchable contacts **172** and **174** from the stationary contacts **178** and **180**. The lower fuse terminal **156** is then disconnected from the line-side terminal element while the fuse **106** remains electrically connected to the lower fuse terminal **156** and to the load side terminal **162**. An arc chute compartment **184** may be formed in the housing **104** beneath the switchable contacts **172** and **174**, and the arc chute may provide a space to contain and dissipate arcing energy as the switchable contacts **172** and **174** are disconnected. Arcing is broken at two locations at each of the contacts **172** and **174**, thus reducing arc intensity, and arcing is contained within the lower portions of the housing **104** and away from the upper surface **118** and the hands of a user when manipulating the switch actuator **110** to disconnect the fuse **106** from the line side terminal **142**.

The housing **104** additionally may include a locking ring **186** which may be used cooperatively with a retention aperture **188** in the switch actuator body **166** to secure the switch actuator **110** in one of the closed position shown in FIG. **2** and the open position shown in FIG. **3**. A locking pin for example, may be inserted through the locking ring **186** and the retention aperture **188** to restrain the switch actuator in the corresponding open or closed position. Additionally, a fuse retaining arm could be provided in the switch actuator **110** to prevent removal of the fuses except when the switch actuator **110** is in the open position.

FIG. **3** illustrates the disconnect module **102** after the switch actuator has been moved in the direction of Arrow A to an open or switched position to disconnect the switchable contacts **172** and **174** from the stationary contacts **178** and **180**. As the actuator is moved to the open position, the actuator body **166** rotates about the shaft **134** and the actuator link **168** is accordingly moved upward in the actuator compartment **164**. As the link **168** moves upward, the link **168** pulls the sliding bar **176** upward in the direction of arrow B to separate the switchable contacts **172** and **174** from the stationary contacts **178** and **180**.

A bias element **200** may be provided beneath the sliding bar **176** and may force the sliding bar **176** upward in the direction of arrow B to a fully opened position separating the contacts **172**, **174** and **178**, **180** from one another. Thus, as the actuator body **166** is rotated in the direction of arrow A, the link **168** is moved past a point of equilibrium and the bias element **200** assists in opening of the contacts **172**, **174** and **178**, **180**. The bias element **200** therefore prevents partial opening of the contacts **172**, **174** and **178**, **180** and ensures a full separation of the contacts to securely break the circuit through the module **102**.

Additionally, when the actuator lever **136** is pulled back in the direction of arrow C to the closed position shown in FIG. **2**, the actuator link **168** is moved to position the sliding bar **176** downward in the direction of arrow D to engage and close the contacts **172**, **174** and **178**, **180** and reconnect the circuit through the fuse **106**. The sliding bar **176** is moved downward against the bias of the bias element **200**, and once in the closed position, the sliding bar **176**, the actuator link **168** and the switch actuator are in static equilibrium so that the switch actuator **110** will remain in the closed position.

In one exemplary embodiment, and as illustrated in FIGS. **2** and **3**, the bias element **200** may be a helical spring element which is loaded in compression in the closed position of the switch actuator **110**. It is appreciated, however, that in an alternatively embodiment a coil spring could be loaded in tension when the switch actuator **110** is closed. Additionally, other known bias elements could be provided to produce opening and/or closing forces to assist in proper operation of the disconnect module **102**. Bias elements may also be utilized for dampening purposes when the contacts are opened.

The lever **136**, when moved between the opened and closed positions of the switch actuator, does not interfere with workspace around the disconnect module **102**, and the lever **136** is unlikely to be inadvertently returned to the closed position from the open position. In the closed position shown in FIG. **3**, the lever **136** is located adjacent to an end of the fuse **106**. The fuse **106** therefore partly shelters the lever **136** from inadvertent contact and unintentional actuation to the closed position. The bias element **200** further provides some resistance to movement of the lever **136** and closing of the contact mechanism. Additionally, the stationary contacts **178** and **180** are at all times protected by the housing **104** of the module **102**, and any risk of electrical shock due to contact with line side terminal **142** and the stationary contacts **178** and **180** is avoided. The disconnect module **102** is therefore considered to be safer than many known fused disconnect devices.

When the modules **102** are ganged together to form a multi-pole device, such as the device **100**, one lever **136** may be extended through and connect to multiple switch actuators **110** for different modules. Thus, all the connected modules **102** may be disconnected and reconnected by manipulating a single lever **136**. That is, multiple poles in the device **100** may be switched simultaneously. Alternatively, the switch actuators **110** of each module **102** in the device **100** may be actuated independently with separate levers **136** for each module.

FIG. **4** is a side elevational view of a further exemplary embodiment of a fusible switching disconnect **102** including, for example, a retractable lockout tab **210** which may extend from the switch actuator **110** when the lever **136** is moved to the open position. The lockout tab **210** may be provided with a lock opening **212** therethrough, and a padlock or other element may be inserted through the lock opening **212** to ensure that the lever **136** may not be moved to the closed position. In different embodiments, the lockout tab **210** may be spring loaded and extended automatically, or may be manually extended from the switch actuator body **166**. When the lever **136** is moved to closed position, the lockout tab **210** may be automatically or manually returned to retracted position wherein the switch actuator **110** may be rotated back to the closed position shown in FIG. **2**.

FIG. **5** is a perspective view of a third exemplary embodiment of a fusible switching disconnect module **220** similar to the module **102** described above but having, for example, a DIN rail mounting slot **222** formed in a lower edge **224** of a housing **226**. The housing **226** may also include openings **228** which may be used to gang the module **220** to other disconnect modules. Side edges **230** of the housing **226** may include connection openings **232** for line side and load connections to box lugs or clamps within the housing **226**. Access openings **234** may be provided in recessed upper surfaces **236** of the housing **226**. A stripped wire, for example, may be extended through the connection openings **232** and a screwdriver may be inserted through the access openings **234** to connect line and load circuitry to the module **220**.

Like the module **102**, the module **220** may include the fuse **106**, the fuse cover **108** and the switch actuator **110**. Switching of the module is accomplished with switchable contacts as described above in relation to the module **102**.

FIGS. **6** and **7** are perspective views of a fourth exemplary embodiment of a fusible switching disconnect module **250** which, like the modules **102** and **220** described above, includes a switch actuator **110** rotatably mounted to the housing on a shaft **134**, a lever **136** extending from the actuator link **168** and a slider bar **176**. The module **250** also includes, for example, a mounting clip **144** and a line side terminal element **142**.

Unlike the modules **102** and **220**, the module **250** may include a housing **252** configured or adapted to receive a rectangular fuse module **254** instead of a cartridge fuse **106**. The fuse module **254** is a known assembly including a rectangular housing **256**, and terminal blades **258** extending from the housing **256**. A fuse element or fuse assembly may be located within the housing **256** and is electrically connected between the terminal blades **258**. Such fuse modules **254** are known and in one embodiment are CubeFuse modules commercially available from Cooper Bussmann of St. Louis, Mo.

A line side fuse clip **260** may be situated within the housing **252** and may receive one of the terminal blades **258** of the fuse module **254**. A load side fuse clip **262** may also be situated within the housing **252** and may receive the other of the fuse terminal blades **258**. The line side fuse clip **260** may be electrically connected to the stationary contact **180**. The load side fuse clip **262** may be electrically connected to the load side terminal **162**. The line side terminal **142** may include the stationary contact **178**, and switching may be accomplished by rotating the switch actuator **110** to engage and disengage the switchable contacts **172** and **174** with the respective stationary contacts **178** and **180** as described above. While the line terminal **142** is illustrated as a bus bar clip, it is recognized that other line terminals may be utilized in other embodiments, and the load side terminal **162** may likewise be another type of terminal in lieu of the illustrated saddle screw terminal in another embodiment.

The fuse module **254** may be plugged into the fuse clips **260**, **262** or extracted therefrom to install or remove the fuse module **254** from the housing **252**. For switching purposes, however, the circuit is connected and disconnected at the contacts **172**, **174** and **178** and **180** rather than at the fuse clips **260** and **262**. Arcing between the disconnected contacts may therefore contained in an arc chute or compartment **270** at the lower portion of the compartment and away from the fuse clips **260** and **262**. By opening the disconnect module **250** with the switch actuator **110** before installing or removing the fuse module **254**, any risk posed by electrical arcing or energized metal at the fuse and housing interface is eliminated. The disconnect module **250** is therefore believed to be safer to use than many known fused disconnect switches.

A plurality of modules **250** may be ganged or otherwise connected together to form a multi-pole device. The poles of the device could be actuated with a single lever **136** or independently operable with different levers.

FIG. **8** is a perspective view of a fifth exemplary embodiment of a fusible switching disconnect device **300** which is, for example, a multi-pole device in an integrated housing **302**. The housing **302** may be constructed to accommodate three fuses **106** in an exemplary embodiment, and is therefore well suited for a three phase power application. The housing **204** may include a DIN rail slot **304** in the illustrated embodiment, although it is understood that other mounting options, mechanisms, and mounting schemes may be utilized in alternative embodiments. Additionally, in one embodiment the housing **204** may have a width dimension D of about 45 mm in accordance with IEC industry standards for contactors, relays, manual motor protectors, and integral starters that are also commonly used in industrial control systems applications. The benefits of the invention, however, accrue equally to devices having different dimensions and devices for different applications.

The housing may also include connection openings **306** and access openings **308** in each side edge **310** which may receive a wire connection and a tool, respectively, to establish line and load connections to the fuses **106**. A single switch actuator **110** may be rotated to connect and disconnect the circuit through the fuses between line and load terminals of the disconnect device **300**.

FIG. **9** is a perspective view of an exemplary switching assembly **320** for the device **300**. The switching assembly may be accommodated in the housing **302** and in an exemplary embodiment may include a set of line terminals **322**, a set of load terminals **324**, a set of lower fuse terminals **326** associated with each respective fuse **106**, and a set of slider bars **176** having switchable contacts mounted thereon for engaging and disengaging stationary contacts mounted to the ends of the line terminals **322** and the lower fuse terminals **324**. An actuator link (not visible in FIG. **9**) may be mounted to an actuator shaft **134**, such that when the lever **136** is rotated, the slider bar **176** may be moved to disconnect the switchable contacts from the stationary contacts. Bias elements **200** may be provided beneath each of the slider bars **176** and assist operation of the switch actuator **110** as described above. As with the foregoing embodiments of modules, a variety of line side and load side terminal structures may be used in various embodiments of the switching assembly.

Retention bars **328** may also be provided on the shaft **134** which extend to the fuses **106** and engage the fuses in an interlocking manner to prevent the fuses **106** from being removed from the device **300** except when the switch actuator **110** is in the open position. In the open position, the retention bars **328** may be angled away from the fuses **106** and the fuses may be freely removed. In the closed position, as shown in FIG. **9**, the retention arms or bars **328** lock the fuse in place. In an exemplary embodiment, distal ends of the bars or arms **328** may be received in slots or detents in the fuses **106**, although the fuses **106** could be locked in another manner as desired.

FIG. **10** is a perspective view of a sixth exemplary embodiment of a fusible switching disconnect device **370** including the disconnect module **300** described above and, for example, an under voltage module **372** mounted to one side of the module **300** and mechanically linked to the switch mechanism in the module **300**. In an exemplary embodiment, the under voltage module **372** may include an electromagnetic coil **374** calibrated to a predetermined voltage range. When the voltage drops below the range, the electromagnetic coil causes the switch contacts in the module **300** to open. A similar module **372** could be employed in an alternative embodiment to open the switch contacts when the voltage experienced by the electromagnetic coil exceeds a predetermined voltage range, and may therefore serve as an overvoltage module. In such a manner, the switch contact in the module **300** could be opened with module **372** and the coil **374** as undervoltage or overvoltage conditions occur.

FIG. **11** is a perspective view of a seventh exemplary embodiment of a fusible switching disconnect device **400** which is essentially the disconnect device **300** and a disconnect device **220** coupled together. The disconnect device **300** provides three poles for an AC power circuit and the device **220** provides an additional pole for other purposes.

FIG. **12** is a perspective view of an eighth embodiment of a fusible switching disconnect module **410** that, like the foregoing embodiments, includes a nonconductive housing **412**, a switch actuator **414** extending through a raised upper surface **415** of the housing **412**, and a cover **416** that provides access to a fuse receptacle (not shown in FIG. **12**) within the housing **412** for installation and replacement of an overcurrent protection fuse (also not shown in FIG. **12**). Like the foregoing embodiments, the housing **412** includes switchable and stationary contacts (not shown in FIG. **12**) that complete or break an electrical connection through the fuse in the housing **412** via movement of an actuator lever **417**.

A DIN rail mounting slot **418** may be formed in a lower edge **420** of the housing **412**, and the DIN rail mounting slot **418** may be dimensioned, for example, for snap-fit engagement and disengagement with a 35 mm DIN rail by hand and without a need of tools. The housing **412** may also include openings **422** that may be used to gang the module **410** to other disconnect modules as explained below. Side edges **424** of the housing **412** may be open ended to provide access to wire lug terminals **426** to establish line and load-side electrical connections external circuitry. Terminal access openings **428** may be provided in recessed upper surfaces **430** of the housing **412**. A stripped wire, for example, may be extended through the sides of the wire lug terminals **426** and a screwdriver may be inserted through the access openings **428** to tighten a terminal screw to clamp the wires to the terminals **426** and connect line and load circuitry to the module **410**. While wire lug terminals **426** are included in one embodiment, it is recognized that a variety of alternative terminal configurations or types may be utilized in other embodiments to establish line and load side electrical connections to the module **410** via wires, cables, bus bars etc.

Like the foregoing embodiments, the housing **412** is sized and dimensioned complementary to and compatible with DIN and IEC standards, and the housing **412** defines an area or footprint on the lower edge **420** for use with standardized openings having a complementary shape and dimension. By way of example only, the housing **412** of the single pole module **410** may have a thickness T of about 17.5 mm for a breaking capacity of up to 32 A; 26 mm for a breaking capacity of up to 50 A, 34 mm for a breaking capacity of up to 125 A; and 40 mm for a breaking capacity of up to 150 A per DIN Standard 43 880. Likewise, it is understood that the module **410** could be fabricated as a multiple pole device such as a three pole device having a dimension T of about 45 mm for a breaking capacity of up to 32 A; 55 mm for a breaking capacity of up to 50 A, and 75 mm for a breaking capacity of up to 125 A. While exemplary dimensions are provided, it is understood that other dimensions of greater or lesser values may likewise be employed in alternative embodiments of the invention.

Additionally, and as illustrated in FIG. **12**, the side edges **424** of the housing **412** may include opposed pairs of vertically oriented flanges **432** spaced from one another and projecting away from the wire lug terminals **426** adjacent the housing upper surface **430** and the sides of the wire lug terminals **426**. The flanges **432**, sometimes referred to as wings, provide an increased surface area of the housing **412** in a horizontal plane extending between the between the wire lug terminals **426** on the opposing side edges **424** of the housing **412** than would otherwise occur if the flanges **432** were not present. That is, a peripheral outer surface area path length extending in a plane parallel to the lower surface **420** of the housing **412** includes the sum of the exterior surface dimensions of one of the pairs of flanges **432** extending from one of the terminals **426**, the exterior dimensions of the respective front or rear panel **431**, **433** of the housing, and the exterior surface dimensions of the opposing flanges **432** extending to the opposite terminal **426**.

Additionally, the housing **412** may also include horizontally extending ribs or shelves **434** spaced from one another and interconnecting the innermost flanges **432** in a lower portion of the housing side edges **424**. The ribs or shelves **434** increase a surface area path length between the terminals **426** in a vertical plane of the housing **412** to meet external requirements for spacing between the terminals **426**. The flanges **432** and ribs **434** result in serpentine-shaped surface areas in horizontal and vertical planes of the housing **412** that permit greater voltage ratings of the device without increasing the footprint of the module **410** in comparison, for example, to the previously described embodiments of FIGS. **1**-**11**. For example, the flanges **432** and the ribs **434**, facilitate a voltage rating of 600 VAC while meeting applicable internal and external spacing requirements between the terminals **426** under applicable UL standards.

The cover **416**, unlike the above-described embodiments, may include a substantially flat cover portion **436**, and an upstanding finger grip portion **438** projecting upwardly and outwardly from one end of the flat cover portion **436** and facing the switch actuator **414**. The cover may be fabricated from a nonconductive material or insulative material such as plastic according to known techniques, and a the flat cover portion **436** may be hinged at an end thereof opposite the finger grip portion **438** so that the cover portion **436** is pivotal about the hinge. By virtue of the hinge, the finger grip portion **438** is movable away from the switch actuator along an arcuate path as further explained below. As illustrated in FIG. **12**, the cover **416** is in a closed position concealing the fuse within the housing **412**, and as explained below, the cover **416** is movable to an open position providing access to the fuse in the disconnect module **410**.

FIG. **13** is a side elevational view of the module **410** with the front panel **431** (FIG. **12**) removed so that internal components and features may be seen. The wire lug terminals **426** and terminal screws **440** are positioned adjacent the side edges **424** of the housing **412**. A fuse **442** is loaded or inserted into the module **410** in a direction substantially perpendicular to the housing upper surface **415**, and as illustrated in FIG. **13**, a longitudinal axis **441** of the fuse **442** extends vertically, as opposed to horizontally, within the housing **412**. The fuse **442** is contained within the housing **412** beneath the cover **416**, and more specifically beneath the flat cover portion **436**. The fuse **442** is situated longitudinally in a fuse receptacle **437** integrally formed in the housing **412**. That is, the fuse receptacle **437** is not movable relative to the housing **402** for loading and unloading of the fuse **442**. The fuse **442** is received in the receptacle **437** with one end of the fuse **442** positioned adjacent and beneath the cover **416** and the module top surface **415** and the other end of the fuse **442** spaced from the cover **416** and the module top surface **415** by a distance equal to the length of the fuse **442**. An actuator interlock **443** is formed with the cover **416** and extends downwardly into the housing **412** adjacent and alongside the fuse receptacle **437**. The actuator interlock **443** of the cover **416** extends opposite and away from the cover finger grip portion **438**.

A cover lockout tab **444** extends radially outwardly from a cylindrical body **446** of the switch actuator **414**, and when the switch actuator **414** is in the closed position illustrated in FIG. **13** completing an electrical connection through the fuse **442**, the cover lockout tab **444** is extended generally perpendicular to the actuator interlock **443** of the cover **416** and a distal end of the cover lockout tab **444** is positioned adjacent the actuator interlock **443** of the cover **416**. The cover lockout tab **444** therefore directly opposes movement of the actuator interlock **443** and resists any attempt by a user to rotate the cover **416** about the cover hinge **448** in the direction of arrow E to open the cover **416**. In such a manner, the fuse **442** cannot be accessed without first rotating the switch actuator **414** in the direction of arrow F to move the pair of switchable contacts **450** away from the stationary contacts **452** via the actuator link **454** and sliding bar **456** carrying the switchable contacts **450** in a similar manner to the foregoing embodiments. Inadvertent contact with energized portions of the fuse **442** is therefore prevented, as the cover **416** can only be opened to access the fuse **442** after the circuit through the fuse **442** is disconnected via the switchable contacts **450**, thereby providing a degree of safety to human operators of the module **410**. Additionally, and because the cover **416** conceals the fuse **442** when the switchable contacts **450** are closed, the outer surfaces of the housing **412** and the cover **416** are touch safe.

A conductive path through the housing **412** and fuse **442** is established as follows. A rigid terminal member **458** is extended from the load side terminal terminal **426** closest to the fuse **442** on one side of the housing **412**. A flexible contact member **460**, such as a wire may be connected to the terminal member **458** at one end and attached to an inner surface of the cover **416** at the opposite end. When the cover **416** is closed, the contact member **460** is brought into mechanical and electrical engagement with an upper ferrule or end cap **462** of the fuse **442**. A movable lower fuse terminal **464** is mechanically and electrically connected to the lower fuse ferrule or end cap **466**, and a flexible contact member **468** interconnects the movable lower fuse terminal **464** to a stationary terminal **470** that carries one of the stationary contacts **452**. The switchable contacts **450** interconnect the stationary contacts **452** when the switch actuator **414** is closed as shown in FIG. **13**. A rigid terminal member **472** completes the circuit path to the line side terminal **426** on the opposing side of the housing **412**. In use, current flows through the circuit path from the line side terminal **426** and the terminal member **472**, through the switch contacts **450** and **452** to the terminal member **470**. From the terminal member **470**, current flows through the contact member **468** to the lower fuse terminal **464** and through the fuse **442**. After flowing through the fuse **442**, current flows to the contact member **460** to the terminal member **458** and to the line side terminal **426**.

The fuse **442** in different exemplary embodiments may be a commercially available 10×38 Midget fuse of Cooper

Bussmann of St. Louis, Mo.; an IEC 10×38 fuse; a class CC fuse; or a D/DO European style fuse. Additionally, and as desired, optional fuse rejection features may be formed in the lower fuse terminal **464** or elsewhere in the module, and cooperate with fuse rejection features of the fuses so that only certain types of fuses may be properly installed in the module **410**. While certain examples of fuses are herein described, it is understood that other types and configurations of fuses may also be employed in alternative embodiments, including but not limited to various types of cylindrical or cartridge fuses and rectangular fuse modules.

A biasing element **474** may be provided between the movable lower fuse terminal **464** and the stationary terminal **470**. The bias element **474** may be for example, a helical coil spring that is compressed to provide an upward biasing force in the direction of arrow G to ensure mechanical and electrical engagement of the movable lower fuse terminal **464** to the lower fuse ferrule **466** and mechanical and electrical engagement between the upper fuse ferrule **462** and the flexible contact member **460**. When the cover **416** is opened in the direction of arrow E to the open position, the bias element **474** forces the fuse upward along its axis **441** in the direction of arrow G as shown in FIG. **14**, exposing the fuse **442** through the raised upper surface **415** of the housing **412** for easy retrieval by an operator for replacement. That is, the fuse **442**, by virtue of the bias element **474**, is automatically lifted and ejected from the housing **412** when the cover **416** is rotated about the hinge **448** in the direction of arrow E after the switch actuator **414** is rotated in the direction of arrow F.

FIG. **15** is a side elevational view of the module **410** with the cover **416** pivoted about the hinge **448** and the switch actuator **414** in the open position. The switchable contacts **450** are moved upwardly by rotation of the actuator **414** and the displacement of the actuator link **454** causes the sliding bar **456** to move along a linear axis **475** substantially parallel to the axis **441** of the fuse **442**, physically separating the switchable contacts **450** from the stationary contacts **452** within the housing **412** and disconnecting the conductive path through the fuse **442**. Additionally, and because of the pair of switchable contacts **450**, electrical arcing is distributed among more than one location as described above.

The bias element **474** deflects when the cover **416** is opened after the actuator **414** is moved to the open position, and the bias element **474** lifts the fuse **442** from the housing **412** so that the upper fuse ferrule **462** is extended above the top surface **415** of the housing. In such a position, the fuse **442** may be easily grasped and pulled out of or extracted from the module **410** along the axis **441**. Fuses may therefore be easily removed from the module **410** for replacement.

Also when the actuator **414** is moved to the open position, an actuator lockout tab **476** extends radially outwardly from the switch actuator body **446** and may accept for example, a padlock to prevent inadvertent closure of the actuator **414** in the direction of arrow H that would otherwise cause the slider bar **456** to move downward in the direction of arrow I along the axis **475** and engage the switchable contacts **450** to the stationary contacts **452**, again completing the electrical connection to the fuse **442** and presenting a safety hazard to operators. When desired, the cover **416** may be rotated back about the hinge **448** to the closed position shown in FIGS. **12** and **13**, and the switch actuator **414** may be rotated in the direction of arrow H to move the cover interlock tab **444** into engagement with the actuator interlock **443** of the cover **416** to maintain each of the cover **416** and the actuator **414** in static equilibrium in a closed and locked position. Closure of the cover **416** requires some force to overcome the resistance of the bias spring **474** in the fuse receptacle **437**, and movement of the actuator to the closed position requires some force to overcome the resistance of a bias element **478** associated with the sliding bar **456**, making inadvertent closure of the contacts and completion of the circuit through the module **410** much less likely.

FIG. **16** is a perspective view of a ganged arrangement of fusible switching disconnect modules **410**. Connector pieces **480** may be fabricated from plastic, for example, and may be used with the openings **422** in the housing panels to retain modules **410** in a side-by-side relation to one another with, for example, snap fit engagement. Pins **482** and/or shims **484**, for example, may be utilized to join or tie the actuator levers **417** and cover finger grip portions **438** of each module **410** to one another so that all of the actuator levers **417** and/or of all of the covers **416** of the combined modules **410** are simultaneously moved with one another. Simultaneous movement of the covers **416** and levers **417** may be especially advantageous for breaking three phase current or, as another example, when switching power to related equipment, such as motor and a cooling fan for the motor so that one does not run without the other.

While single pole modules **410** ganged to one another to form multiple pole devices has been described, it is understood that a multiple pole device having the features of the module **410** could be constructed in a single housing with appropriate modification of the embodiment shown in FIGS. **8** and **9**, for example.

FIG. **17** is a perspective view of a ninth embodiment of a fusible switching disconnect module **500** that, like the foregoing embodiments, includes a single pole housing **502**, a switch actuator **504** extending through a raised upper surface **506** of the housing **502**, and a cover **508** that provides access to a fuse receptacle (not shown in FIG. **17**) within the housing **502** for installation and replacement of an overcurrent protection fuse (also not shown in FIG. **17**). Like the foregoing embodiments, the housing **502** includes switchable and stationary contacts (not shown in FIG. **17**) that connect or disconnect an electrical connection through the fuse in the housing **502** via movement of an actuator lever **510**.

Similar to the module **410**, the module **500** may include a DIN rail mounting slot **512** formed in a lower edge **514** of the housing **502** for mounting of the housing **502** without a need of tools. The housing **502** may also include an actuator opening **515** providing access to the body of the switch actuator **504** so that the actuator **504** may be rotated between the open and closed positions in an automated manner and facilitate remote control of the module **500**. Openings **516** are also provided that may be used to gang the module **500** to other disconnect modules. A curved or arcuate tripping guide slot **517** is also formed in a front panel of the housing **502**. A slidable tripping mechanism, described below, is selectively positionable within the slot **517** to trip the module **500** and disconnect the current path therethrough upon an occurrence of predetermined circuit conditions. The slot **517** also provides access to the tripping mechanism for manual tripping of the mechanism with a tool, or to facilitate remote tripping capability.

Side edges **518** of the housing **502** may be open ended to provide access to line and load side wire lug terminals **520** to establish line and load-side electrical connections to the module **500**, although it is understood that other types of terminals may be used. Terminal access openings **522** may be provided in recessed upper surfaces **524** of the housing **502** to receive a stripped wire or other conductor extended through the sides of the wire lug terminals **520**, and a screwdriver may be inserted through the access openings **522** to connect line and load circuitry to the module **500**. Like the foregoing embodiments, the housing **502** is sized and dimensioned complementary to and compatible with DIN and IEC standards, and the housing **502** defines an area or footprint on the lower surface **514** of the housing for use with standardized openings having a complementary shape and dimension.

Like the module **410** described above, the side edges **518** of the housing **502** may include opposed pairs of vertically oriented flanges or wings **526** spaced from one another and projecting away from the wire lug terminals **520** adjacent the housing upper surface **524** and the sides of the wire lug terminals **520**. The housing **502** may also include horizontally extending ribs or shelves **528** spaced from one another and interconnecting the innermost flanges **526** in a lower portion of the housing side edges **518**. The flanges **526** and ribs **528** result in serpentine-shaped surface areas in horizontal and vertical planes of the housing **502** that permit greater voltage ratings of the device without increasing the footprint of the module **500** as explained above.

The cover **508**, unlike the above-described embodiments, may include a contoured outer surface defining a peak **530** and a concave section **532** sloping downwardly from the peak **530** and facing the switch actuator **504**. The peak **530** and the concave section **532** form a finger cradle area on the surface of the cover **508** and is suitable for example, to serve as a thumb rest for an operator to open or close the cover **508**. The cover **508** may be hinged at an end thereof closest to the peak **530** so that the cover **508** is pivotal about the hinge and the cover **508** is movable away from the switch actuator **504** along an arcuate path. As illustrated in FIG. **17**, the cover **508** is in a closed touch safe position concealing the fuse within the housing **502**, and as explained below, the cover **508** is movable to an open position providing access to the fuse.

FIG. **18** is a side elevational view of a portion of the fusible switching disconnect module **500** with a front panel thereof removed so that internal components and features may be seen. In some aspects the module **500** is similar to the module **410** described above in its internal components, and for brevity like features of the modules **500** and **410** are indicated with like reference characters in FIG. **18**.

The wire lug terminals **520** and terminal screws **440** are positioned adjacent the side edges **518** of the housing **502**. The fuse **442** is vertically loaded into the housing **502** beneath the cover **508**, and the fuse **442** is situated in the non-movable fuse receptacle **437** formed in the housing **502**. The cover **508** may be formed with a conductive contact member that may be, for example, cup-shaped to receive the upper fuse ferrule **462** when the cover **508** is closed.

A conductive circuit path is established from the line side terminal **520** and the terminal member **472**, through the switch contacts **450** and **452** to the terminal member **470**. From the terminal member **470**, current flows through the contact member **468** to the lower fuse terminal **464** and through the fuse **442**. After flowing through the fuse **442**, current flows from the conductive contact member **542** of the cover **508** to the contact member **460** connected to the conductive contact member **542**, and from the contact member **460** to the terminal member **458** and to the line side terminal **426**.

A biasing element **474** may be provided between the movable lower fuse terminal **464** and the stationary terminal **470** as described above to ensure mechanical and electrical connection between the cover contact member **542** and the upper fuse ferrule **462** and between the lower fuse terminal **464** and the lower fuse ferrule **466**. Also, the bias element **474** automatically ejects the fuse **442** from the housing **502** as described above when the cover **508** is rotated about the hinge **448** in the direction of arrow E after the switch actuator **504** is rotated in the direction of arrow F.

Unlike the module **410**, the module **500** may further include a tripping mechanism **544** in the form of a slidably mounted trip bar **545** and a solenoid **546** connected in parallel across the fuse **442**. The trip bar **545** is slidably mounted to the tripping guide slot **517** formed in the housing **502**, and in an exemplary embodiment the trip bar **545** may include a solenoid arm **547**, a cover interlock arm **548** extending substantially perpendicular to the solenoid arm **547**, and a support arm **550** extending obliquely to each of the solenoid arm **547** and cover interlock arm **548**. The support arm **550** may include a latch tab **552** on a distal end thereof. The body **446** of the switch actuator **504** may be formed with a ledge **554** that cooperates with the latch tab **552** to maintain the trip bar **545** and the actuator **504** in static equilibrium with the solenoid arm **547** resting on an upper surface of the solenoid **546**.

A torsion spring **555** is connected to the housing **502** one end and the actuator body **446** on the other end, and the torsion spring **555** biases the switch actuator **504** in the direction of arrow F to the open position. That is, the torsion spring **555** is resistant to movement of the actuator **504** in the direction of arrow H and tends to force the actuator body **446** to rotate in the direction of arrow F to the open position. Thus, the actuator **504** is failsafe by virtue of the torsion spring **555**. If the switch actuator **504** is not completely closed, the torsion spring **555** will force it to the open position and prevent inadvertent closure of the actuator switchable contacts **450**, together with safety and reliability issues associated with incomplete closure of the switchable contacts **450** relative to the stationary contacts **452**.

In normal operating conditions when the actuator **504** is in the closed position, the tendency of the torsion spring **555** to move the actuator to the open position is counteracted by the support arm **550** of the trip bar **545** as shown in FIG. **18**. The latch tab **552** of the support arm **550** engages the ledge **554** of the actuator body **446** and holds the actuator **504** stably in static equilibrium in a closed and locked position. Once the latch tab **552** is released from the ledge **554** of the actuator body **446**, however, the torsion spring **555** forces the actuator **504** to the open position.

An actuator interlock **556** is formed with the cover **508** and extends downwardly into the housing **502** adjacent the fuse receptacle **437**. The cover interlock arm **548** of the trip arm **545** is received in the actuator interlock **556** of the cover **508** and prevents the cover **508** from being opened unless the switch actuator **504** is rotated in the direction of arrow F as explained below to move the trip bar **545** and release the cover interlock arm **548** of the trip bar **545** from the actuator interlock **556** of the cover **508**. Deliberate rotation of the actuator **504** in the direction of arrow F causes the latch tab **552** of the support arm **550** of the trip bar **545** to be pivoted away from the actuator and causes the solenoid arm **547** to become inclined or angled relative to the solenoid **546**. Inclination of the trip bar **545** results in an unstable position and the torsion spring **555** forces the actuator **504** to rotate and further pivot the trip bar **545** to the point of release.

Absent deliberate movement of the actuator to the open position in the direction of arrow F, the trip bar **545**, via the interlock arm **548**, directly opposes movement of the cover **508** and resists any attempt by a user to rotate the cover **508** about the cover hinge **448** in the direction of arrow E to open the cover **508** while the switch actuator **504** is closed and the switchable contacts **450** are engaged to the stationary contacts **452** to complete a circuit path through the fuse **442**. Inadvertent contact with energized portions of the fuse **442** is therefore prevented, as the fuse can only be accessed when the circuit through the fuse is broken via the switchable contacts **450**, thereby providing a degree of safety to human operators of the module **500**.

Upper and lower solenoid contact members **557**, **558** are provided and establish electrical contact with the respective upper and lower ferrules **462**, **466** of the fuse **442** when the cover **508** is closed over the fuse **442**. The contact members **557**, **558** establish, in turn, electrical contact to a circuit board **560**. Resistors **562** are connected to the circuit board **560** and define a high resistance parallel circuit path across the ferrules **462**, **466** of the fuse **442**, and the solenoid **546** is connected to this parallel circuit path on the circuit board **560**. In an exemplary embodiment, the resistance is selected so that, in normal operation, substantially all of the current flow passes through the fuse **442** between the fuse ferrules **462**, **466** instead of through the upper and lower solenoid contact members **557**, **558** and the circuit board **560**. The coil of the solenoid **546** is calibrated so that when the solenoid **546** experiences a predetermined voltage, the solenoid generates an upward force in the direction of arrow G that causes the trip bar **545** to be displaced in the tripping guide slot **517** along an arcuate path defined by the slot **517**.

As those in the art may appreciate, the coil of the solenoid **546** may be calibrated to be responsive to a predetermined undervoltage condition or a predetermined overvoltage condition as desired. Additionally, the circuit board **560** may include circuitry to actively control operation of the solenoid **546** in response to circuit conditions. Contacts may further be provided on the circuit board **560** to facilitate remote control tripping of the solenoid **546**. Thus, in response to abnormal circuit conditions that are predetermined by the calibration of the solenoid coil or control circuitry on the board **560**, the solenoid **546** activates to displace the trip bar **545**. Depending on the configuration of the solenoid **546** and/or the board **560**, opening of the fuse **442** may or may not trigger an abnormal circuit condition causing the solenoid **546** to activate and displace the trip bar **545**.

As the trip bar **545** traverses the arcuate path in the guide slot **517** when the solenoid **546** operates, the solenoid arm **547** is pivoted and becomes inclined or angled relative to the solenoid **546**. Inclination of the solenoid arm **547** causes the trip bar **545** to become unstable and susceptible to force of the torsion spring **555** acting on the trip arm latch tab **552** via the ledge **554** in the actuator body **446**. As the torsion spring **555** begins to rotate the actuator **504**, the trip bar **545** is further pivoted due to engagement of the trip arm latch tab **552** and the actuator ledge **554** and becomes even more unstable and subject to the force of the torsion spring. The trip bar **545** is further moved and pivoted by the combined action of the guide slot **517** and the actuator **504** until the trip arm latch tab **552** is released from the actuator ledge **554**, and the interlock arm **548** of the trip bar **545** is released from the actuator interlock **556**. At this point, each of the actuator **504** and the cover **508** are freely rotatable.

FIG. **19** is a side elevational view of the fusible switching disconnect module **500** illustrating the solenoid **546** in a tripped position wherein a solenoid plunger **570** is displaced upwardly and engages the trip bar **545**, causing the trip bar **545** to move along the curved guide slot **517** and become inclined and unstable relative to the plunger. As the trip bar **545** is displaced and pivoted to become unstable, the torsion spring **555** assists in causing the trip bar **545** to become more unstable as described above, until the ledge **554** of the actuator body **446** is released from the latch tab **552** of the trip bar **545**, and the torsion spring **555** forces the actuator **504** to rotate completely to the open position shown in FIG. **19**. As the actuator **504** rotates to the open position, the actuator link **454** pulls the sliding bar **456** upward along the linear axis **475** and separates the switchable contacts **450** from the stationary contacts **452** to open or disconnect the circuit path between the housing terminals **520**. Additionally, the pivoting of the trip bar **545** releases the actuator interlock **556** of the cover **508**, allowing the bias element **474** to force the fuse upwardly from the housing **502** and causing the cover **508** to pivot about the hinge **448** so that the fuse **442** is exposed for easy removal and replacement.

FIG. **20** is a perspective view of the fusible switching disconnect module **500** in the tripped position and the relative positions of the actuator **504**, the trip bar **545** and the cover **508**. As also shown in FIG. **20**, the sliding bar **456** carrying the switchable contacts **450** may be assisted to the open position by a first bias element **572** external to the sliding bar **456** and a second bias element **574** internal to the sliding bar **456**. The bias elements **572**, **574** may be axially aligned with one another but oppositely loaded in one embodiment. The bias elements **572**, **574** may be for example, helical coil spring elements, and the first bias element **572** may be loaded in compression, for example, while the second bias element **574** is loaded in tension. Therefore, the first bias element **572** exerts an upwardly directed pushing force on the sliding bar **456** while the second bias element **574** exerts an upwardly directed pulling force on the sliding bar **456**. The combined forces of the bias elements **572**, **574** force the sliding bar in an upward direction indicated by arrow G when the actuator is rotated to the open position as shown in FIG. **20**. The double spring action of the bias elements **572**, **574**, together with the torsion spring **555** (FIGS. **18** and **19**) acting on the actuator **504** ensures a rapid, automatic, and complete separation of the switchable contacts **450** from the fixed contacts **452** in a reliable manner. Additionally, the double spring action of the bias elements **572**, **574** effectively prevents and/or compensates for contact bounce when the module **500** is operated.

As FIG. **20** also illustrates, the actuator interlock **556** of the cover **508** is substantially U-shaped in an exemplary embodiment. As seen in FIG. **21** the interlock **556** extends downwardly into the housing **502** when the cover **508** is in the closed position over the fuse **442**, loading the bias element **474** in compression. FIG. **22** illustrates the cover interlock arm **548** of the trip bar **545** aligned with the actuator interlock **556** of the cover **508** when the cover **508** is in the closed position. In such a position, the actuator **504** may be rotated back in the direction of arrow H to move the sliding bar **456** downward in the direction of arrow I to engage the switchable contacts **450** to the stationary contacts **452** of the housing **502**. As the actuator **504** is rotated in the direction of arrow H, the trip bar **545** is pivoted back to the position shown in FIG. **18**, stably maintaining the actuator **504** in the closed position in an interlocked arrangement with the cover **508**. The trip bar **545** may be spring loaded to further assist the tripping action of the module **500** and/or the return of the trip bar **545** to the stable position, or still further to bias the trip bar **545** to a predetermined position with respect to the tripping guide slot **517**.

FIGS. **23** and **24** illustrate a tenth embodiment of a fusible switching disconnect device **600** including a disconnect module **500** and an auxiliary contact module **602** coupled or ganged to the housing **502** in a side-by-side relation to the module **500** via the openings **516** (FIG. **17**) in the module **500**.

The auxiliary contact module **602** may include a housing **603** generally complementary in shape to the housing **502** of the module **500**, and may include an actuator **604** similar to the actuator **508** of the module **500**. An actuator link **606** may interconnect the actuator **604** and a sliding bar **608**. The sliding bar **608** may carry, for example, two pairs of switchable contacts **610** spaced from another. One of the pairs of switchable contacts **610** connects and disconnects a circuit path between a first set of auxiliary terminals **612** and rigid terminal members **614** extending from the respective terminals **612** and each carrying a respective stationary contact for engagement and disengagement with the first set of switchable contacts **610**. The other pair of switchable contacts **610** connects and disconnects a circuit path between a second set of auxiliary terminals **616** and rigid terminal members **618** extending from the respective terminals **616** and each carrying a respective stationary contact for engagement and disengagement with the second set of switchable contacts **610**.

By joining or tying the actuator lever **620** of the auxiliary contact module **602** to the actuator lever **510** of the disconnect module **500** with a pin or a shim, for example, the actuator **604** of the auxiliary contact module **602** may be moved or tripped simultaneously with the actuator **508** of the disconnect module **500**. Thus, auxiliary connections may be connected and disconnected together with a primary connection established through the disconnect module **500**. For example, when the primary connection established through the module **500** powers an electric motor, an auxiliary connection to a cooling fan may be made to the auxiliary contact module via one of the sets of terminals **612** and **616** so that the fan and motor will be powered on and off simultaneously by the device **600**. As another example, one of the auxiliary connections through the terminals **612** and **616** of the auxiliary contact module **602** may be used for remote indication purposes to signal a remote device of the status of the device as being opened or closed to connect or disconnect circuits through the device **600**.

While the auxiliary contact features have been described in the context of an add-on module **602**, it is understood that the components of the module **602** could be integrated into the module **500** if desired. Single pole or multiple pole versions of such a device could likewise be provided.

FIGS. **25-27** illustrate an eleventh embodiment of a fusible switching disconnect device **650** including a disconnect module **500** and a monitoring module **652** coupled or ganged to the housing **502** of the module **500** via the openings **516** (FIG. **17**) in the module **500**.

The monitoring module **652** may include a housing **654** generally complementary in shape to the housing **502** of the module **500**. A sensor board **656** is located in the housing **652**, and flexible contact members **658**, **660** are respectively connected to each of the ferrules **462**, **466** (FIG. **18**) of the fuse **442** (FIG. **1**) in the disconnect module **500** via, for example, the upper and lower solenoid contact members **557**, **558** (FIG. **18**) that establish a parallel circuit path across the fuse ferrules **462**, **466**. The sensor board **656** includes a sensor **662** that monitors operating conditions of the contact members **566**, **568** and outputs a signal to an input/output element **664** powered by an onboard power supply such as a battery **670**. When predetermined operating conditions are detected with the sensor **662**, the input/output element **664** outputs a signal to a output signal port **672** or alternatively to a communications device **674** that wirelessly communicates with a remotely located overview and response dispatch system **676** that alerts, notifies, and summons maintenance personnel or responsible technicians to respond to tripping and opened fuse conditions to restore or re-energize associated circuitry with minimal downtime.

Optionally, an input signal port **678** may be included in the monitoring module **652**. The input signal port **678** may be interconnected with an output signal port **672** of another monitoring module, such that signals from multiple monitoring modules may be daisy chained together to a single communications device **674** for transmission to the remote system **676**. Interface plugs (not shown) may be used to interconnect one monitoring module to another in an electrical system.

In one embodiment, the sensor **662** is a voltage sensing latch circuit having first and second portions optically isolated from one another. When the primary fuse element **680** of the fuse **442** opens to interrupt the current path through the fuse, the sensor **662** detects the voltage drop across the terminal elements T_1 and T_2 (the solenoid contact members **557** and **558**) associated with the fuse **442**. The voltage drop causes one of the circuit portions, for example, to latch high and provide an input signal to the input/output element **664**. Acceptable sensing technology for the sensor **662** is available from, for example, SymCom, Inc. of Rapid City, S. Dak.

While in the exemplary embodiment, the sensor **662** is a voltage sensor, it is understood that other types of sensing could be used in alternative embodiments to monitor and sense an operating state of the fuse **442**, including but not limited to current sensors and temperature sensors that could be used to determine whether the primary fuse element **680** has been interrupted in an overcurrent condition to isolate or disconnect a portion of the associated electrical system.

In a further embodiment, one or more additional sensors or transducers **682** may be provided, internal or external to the monitoring module **652**, to collect data of interest with respect to the electrical system and the load connected to the fuse **442**. For example, sensors or transducers **682** may be adapted to monitor and sense vibration and displacement conditions, mechanical stress and strain conditions, acoustical emissions and noise conditions, thermal imagery and thermalography states, electrical resistance, pressure conditions, and humidity conditions in the vicinity of the fuse **442** and connected loads. The sensors or transducers **682** may be coupled to the input/output device **664** as signal inputs. Video imaging and surveillance devices (not shown) may also be provided to supply video data and inputs to the input/output element **664**.

In an exemplary embodiment, the input/output element **664** may be a microcontroller having a microprocessor or equivalent electronic package that receives the input signal from the sensor **662** when the fuse **442** has operated to interrupt the current path through the fuse **442**. The input/output element **664**, in response to the input signal from the sensor **662**, generates a data packet in a predetermined message protocol and outputs the data packet to the signal port **672** or the communications device **674**. The data packet may be formatted in any desirable protocol, but in an exemplary embodiment includes at least a fuse identification code, a fault code, and a location or address code in the data packet so that the operated fuse may be readily identified and its status confirmed, together with its location in the electrical system by the remote system **676**. Of course, the data packet could contain other information and codes of interest, including but not limited to system test codes, data collection codes, security codes and the like that is desirable or advantageous in the communications protocol.

Additionally, signal inputs from the sensor or transducer **682** may be input the input/output element **664**, and the input/output element **664** may generate a data packet in a predetermined message protocol and output the data packet to the signal port **672** or the communications device **674**. The data packet may include, for example, codes relating to vibration and displacement conditions, mechanical stress and strain conditions, acoustical emissions and noise conditions, thermal imagery and thermalography states, electrical resistance, pressure conditions, and humidity conditions in the vicinity of the fuse **442** and connected loads. Video and imaging data, supplied by the imaging and surveillance devices **682** may also be provided in the data packet. Such data may be utilized for troubleshooting, diagnostic, and event history logging for detailed analysis to optimize the larger electrical system.

The transmitted data packet from the communications device **674**, in addition to the data packet codes described above, also includes a unique transmitter identifier code so that the overview and response dispatch system **676** may identify the particular monitoring module **652** that is sending a data packet in a larger electrical system having a large number of monitoring modules **652** associated with a number of fuses. As such, the precise location of the affected disconnect module **500** in an electrical system may be identified by the overview and response dispatch system **676** and communicated to responding personnel, together with other information and instruction to quickly reset affected circuitry when one or more of the modules **500** operates to disconnect a portion of the electrical system.

In one embodiment, the communications device **674** is a low power radio frequency (RF) signal transmitter that digitally transmits the data packet in a wireless manner. Point-to-point wiring in the electrical system for fuse monitoring purposes is therefore avoided, although it is understood that point-to-point wiring could be utilized in some embodiments of the invention. Additionally, while a low power digital radio frequency transmitter has been specifically described, it is understood that other known communication schemes and equivalents could alternatively be used if desired.

Status indicators and the like such as light emitting diodes (LED's) may be provided in the monitoring module **652** to locally indicate an operated fuse **442** or a tripped disconnect condition. Thus, when maintenance personnel arrives at the location of the disconnect module **500** containing the fuse **442**, the status indicators may provide local state identification of the fuses associated with the module **500**.

Further details of such monitoring technology, communication with the remote system **676**, and response and operation of the system **676** are disclosed in commonly owned U.S. patent application Ser. No. 11/223,385 filed Sep. 9, 2005 and entitled Circuit Protector Monitoring Assembly, Kit and Method.

While the monitoring features have been described in the context of an add-on module **652**, it is understood that the components of the module **652** could be integrated into the module **500** if desired. Single pole or multiple pole versions of such a device could likewise be provided. Additionally, the monitoring module **652** and the auxiliary contact module could each be used with a single disconnect module **500** if desired, or alternative could be combined in an integrated device with single pole or multiple pole capability.

FIG. **28** is a side elevational view of a portion of a twelfth embodiment of a fusible switching disconnect module **700** that is constructed similarly to the disconnect module **500** described above but includes a bimetallic overload element **702** in lieu of the solenoid described previously. The overload element **702** is fabricated from strips of two different types of metallic or conductive materials having different coefficients of thermal expansion joined to one another, and a resistance alloy joined to the metallic elements. The resistance alloy may be electrically isolated from the metallic strips with insulative material, such as a double cotton coating in an exemplary embodiment.

In use, the resistance alloy strip is joined to the contact members **557** and **558** and defines a high resistance parallel connection across the ferrules **462** and **466** of the fuse **442**. The resistance alloy is heated by current flowing through the resistance alloy and the resistance alloy, in turn heats the bimetal strip. When a predetermined current condition is approached, the differing rates of coefficients of thermal expansion in the bimetal strip causes the overload element **702** to bend and displace the trip bar **545** to the point of release where the spring loaded actuator **504** and sliding bar **456** move to the opened positions to disconnect the circuit through the fuse **442**.

The module **700** may be used in combination with other modules **500** or **700**, auxiliary contact modules **602**, and monitoring modules **652**. Single pole and multiple pole versions of the module **700** may also be provided.

FIG. **29** is a side elevational view of a portion of a thirteenth embodiment of a fusible switching disconnect module **720** that is constructed similarly to the disconnect module **500** described above but includes an electronic overload element **722** that monitors current flow through the fuse by virtue of the contact members **557** and **558**. When the current reaches a predetermined level, the electronic overload element **722** energizes a circuit to power the solenoid and trip the module **720** as described above. The electronic overload element **722** may likewise be used to reset the module after a tripping event.

The module **702** may be used in combination with other modules **500** or **700**, auxiliary contact modules **602**, and monitoring modules **652**. Single pole and multiple pole versions of the module **700** may also be provided.

Embodiments of fusible disconnect devices are therefore described herein that may be conveniently switched on and off in a convenient and safe manner without interfering with workspace around the device. The disconnect devices may be reliably switch a circuit on and off in a cost effective manner and may be used with standardized equipment in, for example, industrial control applications. Further, the disconnect modules and devices may be provided with various mounting and connection options for versatility in the field. Auxiliary contact and overload and underload tripping capability is provided, together with remote monitoring and control capability.

FIG. **30** is a side elevational view of a portion of a fourteenth embodiment of a fusible switching disconnect device **750** providing numerous additional benefits and advantages apart from those discussed above. Method aspects implementing advantageous features will be in part apparent and in part explicitly discussed in the description below.

The device **750** includes a disconnect housing **752** fabricated from an electrically nonconductive or insulative material such as plastic, and the fuse module housing **752** is configured or adapted to receive a retractable rectangular fuse module **754**. While a rectangular fuse module **754** is shown in the exemplary embodiment illustrated, it is recognized that the disconnect housing **754** may alternatively be configured to receive and engage another type of fuse, such as cylindrical or cartridge fuses familiar to those in the art and as described above. The disconnect housing **752** and its internal components described below, are sometimes referred to as a base assembly that receives the retractable fuse module **754**.

The fuse module **754** in the exemplary embodiment shown includes a rectangular housing **756** fabricated from an electrically nonconductive or insulative material such as plastic, and conductive terminal elements in the form or terminal blades **758** extending from the housing **756**. A primary fuse element or fuse assembly is located within the housing **756** and is electrically connected between the terminal blades **758** to provide a current path therebetween. Such fuse modules **754** are known and in one embodiment the rectangular fuse module is a CUBEFuse™ power fuse module commercially available from Cooper Bussmann of St. Louis, Mo. The fuse module **754** provides overcurrent protection via the primary fuse element therein that is configured to melt, disintegrate or otherwise fail and permanently open the current path through the fuse element between the terminal blades **758** in response to predetermined current conditions flowing through the fuse element in use. When the fuse element opens in such a manner, the fuse module **754** must be removed and replaced to restore affected circuitry.

A variety of different types of fuse elements, or fuse element assemblies, are known and may be utilized in the fuse module **754** with considerable performance variations in use. Also, the fuse module **754** may include fuse state indication features, a variety of which are known in the art, to identify the permanent opening of the primary fuse element such that the fuse module **754** can be quickly identified for replacement via a visual change in appearance when viewed from the exterior of the fuse module housing **756**. Such fuse state indication features may involve secondary fuse links or elements electrically connected in parallel with the primary fuse element in the fuse module **754**.

A conductive line side fuse clip **760** may be situated within the disconnect housing **752** and may receive one of the terminal blades **758** of the fuse module **754**. A conductive load side fuse clip **762** may also be situated within the disconnect housing **752** and may receive the other of the fuse terminal blades **758**. The line side fuse clip **760** may be electrically connected to a first line side terminal **764** provided in the disconnect housing **752**, and the first line side terminal **764** may include a stationary switch contact **766**. The load side fuse clip **762** may be electrically connected to a load side connection terminal **768**. In the example shown, the load side connection terminal **768** is a box lug terminal operable with a screw **770** to clamp or release an end of a connecting wire to establish electrical connection with load side electrical circuitry. Other types of load side connection terminals are known, however, and may be provided in alternative embodiments.

A rotary switch actuator **772** is further provided in the disconnect housing **752**, and is mechanically coupled to an actuator link **774** that, in turn, is coupled to a sliding actuator bar **776**. The actuator bar **776** carries a pair of switch contacts **778** and **780**. In an exemplary embodiment, the switch actuator **772**, the link **774** and the actuator bar **778** may be fabricated from nonconductive materials such as plastic. A second conductive line side terminal **782** including a stationary contact **784** is also provided, and a line side connecting terminal **785** is also provided in the disconnect housing **752**. In the example shown, the line side connection terminal **785** is a box lug terminal operable with a screw **786** to clamp or release an end of a connecting wire to establish electrical connection with line side electrical circuitry. Other types of line side connection terminals are known, however, and may be provided in alternative embodiments. While in the illustrated embodiment the line side connecting terminal **785** and the load side connecting terminal **768** are of the same type (i.e., both are box lug terminals), it is contemplated that different types of connection terminals could be provided on the line and load sides of the disconnect housing **752** if desired.

Electrical connection of the device **750** to power supply circuitry, sometimes referred to as the line side, may be accomplished in a known manner using the line side connecting terminal **785**. Likewise, electrical connection to load side circuitry may be accomplished in a known manner using the load side connecting terminal **768**. As mentioned previously, a variety of connecting techniques are known (e.g., spring clamp terminals and the like) and may alternatively be utilized to provide a number of different options to make the electrical connections in the field. The configuration of the connecting terminals **784** and **768** accordingly are exemplary only.

In the position shown in FIG. **30**, the disconnect device **750** is shown in the closed position with the switch contacts **780** and **778** mechanically and electrically engaged to the stationary contacts **784** and **766**, respectively. As such, and as further shown in FIG. **33** when the device **750** is connected to line side circuitry **790** with a first connecting wire **792** via the line side connecting terminal **785**, and also when the load side terminal **768** is connected to load side circuitry **794** with a connecting wire **796**, a circuit path is completed through conductive elements in the disconnect housing **752** and the fuse module **754** when the fuse module **754** is installed and when the primary fuse element therein is a non-opened, current carrying state.

Specifically, and referring again to FIGS. **30** and **33**, electrical current flow through the device **750** is as follows when the switch contacts **778** and **780** are closed, when the device **750** is connected to line and load side circuitry as shown in FIG. **33**, and when the fuse module **754** is installed. Electrical current flows from the line side circuitry **790** through the line side connecting wire **792**, and from the wire **792** to and through the line side connecting terminal **785**. From the line side connecting terminal **785** current then flows to and through the second line terminal **782** and to the stationary contact **784**. From the stationary contact **784** current flows to and through the switch contact **780**, and from the switch contact **780** current flows to and through the switch contact **778**. From the switch contact **778** current flows to and through the stationary contact **766**, and from the stationary contact **766** current flows to and through the first line side terminal **764**. From the first line side terminal **764** current flows to and through the line side fuse clip **760**, and from the line side fuse clip **760** current flows to and through the first mating fuse terminal blade **758**. From the first terminal blade **758** current flows to and through the primary fuse element in the fuse module **754**, and from the primary fuse element to and through the second fuse terminal blade **758**. From the second terminal blade **758** current flows to and through the load side fuse clip **762**, and from the load side fuse clip **762** to and through the load side connecting terminal **768**. Finally, from the connecting terminal **768** current flows to the load side circuitry **794** via the wire **796** (FIG. **33**). As such, a circuit path or current path is established through the device **750** that includes the fuse element of the fuse module **754**.

Disconnect switching to temporarily open the current path in the device may be accomplished in multiple ways. First, and as shown in FIG. **30**, a portion of the switch actuator projects through an upper surface of the disconnect housing **752** and is therefore accessible to be grasped for manual manipulation by a person. Specifically, the switch actuator **772** may be rotated from a closed position as shown in FIG. **30** to an open position in the direction of arrow A, causing the actuator link **774** to move the sliding bar **776** linearly in the direction of arrow B and moving the switch contacts **780** and **778** away from the stationary contacts **784** and **766**. Eventually, the switch contacts **780** and **778** become mechanically and electrically disengaged from the stationary contacts **784** and **766** and the circuit path between the first and second line terminals **764** and **782**, which includes the primary fusible element of the fuse module **754**, may be opened via the separation of the switch contacts **780** and **764** when the fuse terminal blades **758** are received in the line and load side fuse clips **760** and **762**.

When the circuit path in the device **750** is opened in such a manner via rotational displacement of the switch actuator **772**, the fuse module **754** becomes electrically disconnected from the first line side terminal **782** and the associated line side connecting terminal **785**. In other words, an open circuit is established between the line side connecting terminal **785** and the first terminal blade **758** of the fuse module **754** that is received in the line side fuse clip **760**. The operation of switch actuator **772** and the displacement of the sliding bar **776** to separate the contacts **780** and **778** from the stationary contacts **784** and **766** may be assisted with bias elements such as the springs described in embodiments above with similar benefits. Particularly, the sliding bar **776** may be biased toward the open position wherein the switch contacts **780** and **778** are separated from the contacts **784** and **786** by a predetermined distance. The dual switch contacts **784** and **766** mitigate electrical arcing concerns as the switch contacts **784** and **766** are engaged and disengaged.

Once the switch actuator **772** of the disconnect device **750** is switched open to interrupt the current path in the device **750** and disconnect the fuse module **754**, the current path in the device **750** may be closed to once again complete the circuit path through the fuse module **754** by rotating the switch actuator **772** in the opposite direction indicated by arrow C in FIG. **30**. As the switch actuator **772** rotates in the direction of arrow C, the actuator link **774** causes the sliding bar **776** to move linearly in the direction of arrow D and bring the switch contacts **780** and **778** toward the stationary contacts **784** and **764** to close the circuit path through the first and second line terminals **764** and **782**. As such, by moving the actuator **772** to a desired position, the fuse module **754** and associated load side circuitry **794** (FIG. **33**) may be connected and disconnected from the line side circuitry **790** (FIG. **33**) while the line side circuitry **790** remains "live" in an energized, full power condition. Alternatively stated, by rotating the switch actuator **772** to separate or join the switch contacts, the load side circuitry **794** may be electrically isolated from the line side circuitry **790** (FIG. **33**), or electrically connected to the line side circuitry **794** on demand.

Additionally, the fuse module **754** may be simply plugged into the fuse clips **760**, **762** or extracted therefrom to install or remove the fuse module **754** from the disconnect housing **752**. The fuse housing **756** projects from the disconnect housing **752** and is open and accessible from an exterior of the disconnect housing **752** so that a person simply can grasp the fuse housing **756** by hand and pull or lift the fuse module **754** in the direction of arrow B to disengage the fuse terminal blades **758** from the line and load side fuse clips **760** and **762** until the fuse module **754** is completely released from the disconnect housing **752**. An open circuit is established between the line and load side fuse clips **760** and **762** when the terminal blades **758** of the fuse module **754** are removed as the fuse module **754** is released, and the circuit path between the fuse clips **760** and **762** is completed when the fuse terminal blades **758** are engaged in the fuse clips **760** and **762** when the fuse module **754** is installed. Thus, via insertion and removal of the fuse module **754**, the circuit path through the device **750** can be opened or closed apart from the position of the switch contacts as described above.

Of course, the primary fuse element in the fuse module **754** provides still another mode of opening the current path through the device **750** when the fuse module is installed in response to actual current conditions flowing through the fuse element. As noted above, however, if the primary fuse element in the fuse module **754** opens, it does so permanently and the only way to restore the complete current path through the device **750** is to replace the fuse module **754** with another one having a non-opened fuse element. As such, and for discussion purposes, the opening of the fuse element in the fuse module **754** is permanent in the sense that the fuse module **750** cannot be reset to once again complete the current path through the device. Mere removal of the fuse module **754**, and also displacement of the switch actuator **772** as described, are in contrast considered to be temporary events and are resettable to easily complete the current path and restore full operation of the affected circuitry by once again installing the fuse module **754** and/or closing the switch contacts.

The fuse module **754**, or a replacement fuse module, can be conveniently and safely grasped by hand via the fuse module housing **756** and moved toward the switch housing **752** to engage the fuse terminal blades **758** to the line and load side fuse clips **760** and **762**. The fuse terminal blades **758** are extendable through openings in the disconnect housing **752** to connect the fuse terminal blades **758** to the fuse clips **760** and **762**. To remove the fuse module **754**, the fuse module housing **756** can be grasped by hand and pulled from the disconnect housing **752** until the fuse module is completely released. As such, the fuse module **754** having the terminal blades **758** may be rather simply and easily plugged into the disconnect housing **752** and the fuse clips **760**, **762**, or unplugged as desired.

Such plug-in connection and removal of the fuse module **754** advantageously facilitates quick and convenient installation and removal of the fuse module **754** without requiring separately supplied fuse carrier elements and without requiring tools or fasteners common to other known fusible disconnect devices. Also, the fuse terminal blades **758** extend through and outwardly project from a common side of the fuse module body **756**, and in the example shown the terminal blades **758** each extend outwardly from a lower side of the fuse housing **756** that faces the disconnect housing **752** as the fuse module **754** is mated to the disconnect housing **752**.

In the exemplary embodiment shown, the fuse terminal blades **758** extending from the fuse module body **756** are generally aligned with one another and extend in respective spaced-apart parallel planes. It is recognized, however, that the terminal blades **758** in various other embodiments may be staggered or offset from one another, need not extend in parallel planes, and can be differently dimensioned or shaped. The shape, dimension, and relative orientation of the terminal blades **758**, and the receiving fuse clips **760** and **762** in the disconnect housing **752** may serve as fuse rejection features that only allow compatible fuses to be used with the disconnect housing **752**. In any event, because the terminal blades **758** project away from the lower side of the fuse housing **756**, a person's hand when handling the fuse module housing **756** for plug in installation (or removal) is physically isolated from the terminal blades **758** and the conductive line and load side fuse clips **760** and **762** that receive the terminal blades **758** as mechanical and electrical connections therebetween are made and broken. The fuse module **754** is therefore touch safe (i.e., may be safely handled by hand to install and remove the fuse module **754** without risk of electrical shock).

The disconnect device **750** is rather compact and occupies a reduced amount of space in an electrical power distribution system including the line side circuitry **790** and the load side circuitry **794**, than other known fusible disconnect devices and arrangements providing similar effect. In the embodiment illustrated in FIG. **30** the disconnect housing **752** is provided with a DIN rail slot **800** that may be used to securely mount the disconnect housing **752** in place with snap-on installation to a DIN rail by hand and without tools. The DIN rail may be located in a cabinet or supported by other structure, and because of the smaller size of the device **750**, a greater number of devices **750** may be mounted to the DIN rail in comparison to conventional fusible disconnect devices.

In another embodiment, the device **750** may be configured for panel mounting by replacing the line side terminal **785**, for example, with a panel mounting clip. When so provided, the device **750** can easily occupy less space in a fusible panelboard assembly, for example, than conventional in-line fuse and circuit breaker combinations. In particular, CUBE-Fuse™ power fuse modules occupy a smaller area, sometimes referred to as a footprint, in the panel assembly than non-rectangular fuses having comparable ratings and interruption capabilities. Reductions in the size of panelboards are therefore possible, with increased interruption capabilities.

In ordinary use, the circuit path or current path through the device **750** is preferably connected and disconnected at the switch contacts **784**, **780**, **778**, **766** rather than at the fuse clips **760** and **762**. By doing so, electrical arcing that may occur when connecting/disconnecting the circuit path may be contained at a location away from the fuse clips **760** and **762** to provide additional safety for persons installing, removing, or replacing fuses. By opening the switch contacts with the switch actuator **772** before installing or removing the fuse module **754**, any risk posed by electrical arcing or energized conductors at the fuse and disconnect housing interface is eliminated. The disconnect device **750** is accordingly believed to be safer to use than many known fused disconnect switches.

The disconnect switching device **750** includes still further features, however, that improve the safety of the device **750** in the event that a person attempts to remove the fuse module **754** without first operating the actuator **772** to disconnect the circuit through the fuse module **754**, and also to ensure that the fuse module **754** is compatible with the remainder of the device **750**. That is, features are provided to ensure that the rating of the fuse module **754** is compatible with the rating of the conductive components in the disconnect housing **752**.

As shown in FIG. **30**, the disconnect housing **752** in one example includes an open ended receptacle or cavity **802** on an upper edge thereof that accepts a portion of the fuse housing **756** when the fuse module **754** is installed with the fuse terminal blades **758** engaged to the fuse clips **760**, **762**. The receptacle **802** is shallow in the embodiment depicted, such that a relatively small portion of the fuse housing **756** is received when the terminal blades **758** are plugged into the disconnect housing **752**. A remainder of the fuse housing **756**, however, generally projects outwardly from the disconnect housing **752** allowing the fuse module housing **756** to be easily accessed and grasped with a user's hand and facilitating a finger safe handling of the fuse module **754** for installation and removal without requiring tools. It is understood, however, that in other embodiments the fuse housing **756** need not project as greatly from the switch housing receptacle when installed as in the embodiment depicted, and indeed could even be substantially entirely contained within the switch housing **752** if desired.

In the exemplary embodiment shown in FIG. **30**, the fuse housing **756** includes a recessed guide rim **804** having a slightly smaller outer perimeter than a remainder of the fuse housing **756**, and the guide rim **804** is seated in the switch housing receptacle **802** when the fuse module **754** is installed. It is understood, however, that the guide rim **804** may be considered entirely optional in another embodiment and need not be provided. The guide rim **804** may in whole or in part serve as a fuse rejection feature that would prevent someone from installing a fuse module **754** having a rating that is incompatible with the conductive components in the disconnect housing **752**. Fuse rejection features could further be provided by modifying the terminal blades **758** in shape, orientation, or relative position to ensure that a fuse module having an incompatible rating cannot be installed.

In contemplated embodiments, the base of the device **750** (i.e., the disconnect housing **752** and the conductive components therein) has a rating that is ½ of the rating of the fuse module **754**. Thus, for example, a base having a current rating of 20 A may preferably be used with a fuse module **754** having a rating of 40 A. Ideally, however, fuse rejection features such as those described above would prevent a fuse module of a higher rating, such as 60 A, from being installed in the base. The fuse rejection features in the disconnect housing **752** and/or the fuse module **754** can be strategically coordinated to allow a fuse of a lower rating (e.g., a fuse module having a current rating of 20 A) to be installed, but to reject fuses having higher current ratings (e.g., 60 A and above in the example being discussed). It can therefore be practically ensured that problematic combinations of fuse modules and bases will not occur. While exemplary ratings are discussed above, they are provided for the sake of illustration rather than limitation. A variety of fuse ratings and base ratings are possible, and the base rating and the fuse module rating may vary in different embodiments and in some embodiments the base rating and the fuse module rating may be the same.

As a further enhancement, the disconnect housing **752** includes an interlock element **806** that frustrates any effort to remove the fuse module **754** while the circuit path through the first and second line terminals **782** and **764** via the switch contacts **784**, **780**, **778**, **766** is closed. The exemplary interlock element **806** shown includes an interlock shaft **808** at a leading edge thereof, and in the locked position shown in FIG. **30** the interlock shaft **808** extends through a hole in the first fuse terminal blade **758** that is received in the line side fuse clip **760**. Thus, as long as the projecting interlock shaft **808** is extended through the opening in the terminal blade **758**, the fuse module **754** cannot be pulled from the fuse clip **762** if a person attempts to pull or lift the fuse module housing **756** in the direction of arrow B. As a result, and because of the interlock element **806**, the fuse terminal blades **758** cannot be removed from the fuse clips **760** and

762 while the switch contacts are closed **778**, **780** are closed and potential electrical arcing at the interface of the fuse clips **760** and **762** and the fuse terminal blades **758** is avoided. Such an interlock element **806** is believed to be beneficial for the reasons stated but could be considered optional in certain embodiments and need not be utilized.

The interlock element **806** is coordinated with the switch actuator **772** so that the interlock element **806** is moved to an unlocked position wherein the first fuse terminal blade **758** is released for removal from the fuse clip **760** as the switch actuator **772** is manipulated to open the device **750**. More specifically, a pivotally mounted actuator arm **810** is provided in the disconnect housing **752** at a distance from the switch actuator **772**, and a first generally linear mechanical link **812** interconnects the switch actuator **772** with the arm **810**. The pivot points of the switch actuator **772** and the arm **810** are nearly aligned in the example shown in FIG. **30**, and as the switch actuator **772** is rotated in the direction of arrow A, the link **812** carried on the switch actuator **772** simultaneously rotates and causes the arm **810** to rotate similarly in the direction of arrow E. As such, the switch actuator **772** and the arm **810** are rotated in the same rotational direction at approximately the same rate.

A second generally linear mechanical link **814** is also provided that interconnects the pivot arm **810** and a portion of the interlock element **806**. As the arm **810** is rotated in the direction of arrow E, the link **814** is simultaneously displaced and pulls the interlock element **806** in the direction of arrow F, causing the projecting shaft **808** to become disengaged from the first terminal blade **758** and unlocking the interlock element **806**. When so unlocked, the fuse module **754** can then be freely removed from the fuse clips **760** and **762** by lifting on the fuse module housing **756** in the direction of arrow B. The fuse module **754**, or perhaps a replacement fuse module **754**, can accordingly be freely installed by plugging the terminal blades **758** into the respective fuse clips **760** and **762**.

As the switch actuator **772** is moved back in the direction of arrow C to close the disconnect device **750**, the first link **812** causes the pivot arm **810** to rotate in the direction of arrow G, causing the second link **814** to push the interlock element **806** in the direction of arrow H until the projecting shaft **808** of the interlock element **806** again passes through the opening of the first terminal blade **758** and assumes a locked position with the first terminal blade **758**. As such, and because of the arrangement of the arm **810** and the links **812** and **814**, the interlock element **806** is slidably movable within the disconnect housing **752** between locked and unlocked positions. This slidable movement of the interlock element **806** occurs in a substantially linear and axial direction within the disconnect housing **752** in the directions of arrow F and H in FIG. **30**.

In the example shown, the axial sliding movement of the interlock element **806** is generally perpendicular to the axial sliding movement of the actuator bar **766** that carries the switchable contacts **778** and **780**. In the plane of FIG. **30**, the movement of the interlock element **806** occurs along a substantially horizontal axis, while the movement of the sliding bar **776** occurs along a substantially vertical axis. The vertical and horizontal actuation of the sliding bar **776** and the interlock element **806**, respectively, contributes to the compact size of the resultant device **750**, although it is contemplated that other arrangements are possible and could be utilized to mechanically move and coordinate positions of the switch actuator **772**, the switch sliding bar **776** and the interlock element **806**. Also, the interlock element **806** may be biased to assist in moving the interlock element to the locked or unlocked position as desired, as well as to resist movement of the switch actuator **772**, the sliding bar **776** and the interlock element **806** from one position to another. For example, by biasing the switch actuator **772** to the opened position to separate the switch contacts, either directly or indirectly via bias elements acting upon the sliding bar **776** or the interlock element **806**, inadvertent closure of the switch actuator **772** to close the switch contacts and complete the current path may be largely, if not entirely frustrated, because once the switch contacts are opened a person must apply a sufficient force to overcome the bias force and move the switch actuator **772** back to the closed position shown in FIG. **30** to reset the device **750** and again complete the circuit path. If sufficient bias force is present, it can be practically ensured that the switch actuator **772** will not be moved to close the switch via accidental or inadvertent touching of the switch actuator **772**.

The interlock element **806** may be fabricated from a nonconductive material such as plastic according to known techniques, and may be formed into various shapes, including but not limited to the shape depicted in FIG. **30**. Rails and the like may be formed in the disconnect housing **752** to facilitate the sliding movement of the interlock element **806** between the locked and unlocked positions.

The pivot arm **810** is further coordinated with a tripping element **820** for automatic operation of the device **750** to open the switch contacts **778**, **780**. That is, the pivot arm **810**, in combination a tripping element actuator described below, and also in combination with the linkage **774**, **812**, and **814** define a tripping mechanism to force the switch contacts **778**, **780** to open independently from the action of any person. Operation of the tripping mechanism is fully automatic, as described below, in response to actual circuit conditions, as opposed to the manual operation of the switch actuator **772** described above. Further, the tripping mechanism is multifunctional as described below to not only open the switch contacts, but to also to displace the switch actuator **772** and the interlock element **806** to their opened and unlocked positions, respectively. The pivot arm **810** and associated linkage may be fabricated from relatively lightweight nonconductive materials such as plastic.

In the example shown in FIG. **30**, the tripping element actuator **810** is an electromagnetic coil such as a solenoid having a cylinder or pin **822**, sometimes referred to as a plunger, that is extendable or retractable in the direction of arrow F and H along an axis of the coil. The coil when energized generates a magnetic field that causes the cylinder or pin **822** to be displaced. The direction of the displacement depends on the orientation of the magnetic field generated so as to push or pull the plunger cylinder or pin **822** along the axis of the coil. The plunger cylinder or pin **822** may assume various shapes (e.g., may be rounded, rectangular or have other geometric shape in outer profile) and may be dimensioned to perform as hereinafter described.

In the example shown in FIG. **30**, when the plunger cylinder or pin **822** is extended in the direction of arrow F, it mechanically contacts a portion of the pivot arm **810** and causes rotation thereof in the direction of arrow E. As the pivot arm **810** rotates, the link **812** is simultaneously moved and causes the switch actuator **772** to rotate in the direction of arrow A, which in turn pulls the link **774** and moves the sliding bar **776** to open the switch contacts **778**, **780**. Likewise, rotation of the pivot arm **810** in the direction of arrow E simultaneously causes the link **814** to move the interlock element **806** in the direction of arrow F to the unlocked position.

It is therefore seen that a single pivot arm **810** and the linkage **812** and **814** mechanically couples the switch actuator **772** and the interlock element **806** during normal operation of the device, and also mechanically couples the switch actuator **772** and the interlock element **806** to the tripping element **820** for automatic operation of the device. In the exemplary embodiment shown, an end of the link **774** connecting the switch actuator **772** and the sliding bar **776** that carries the switch contacts **778**, **780** is coupled to the switch actuator **772** at approximately a common location as the end of the link **812**, thereby ensuring that when the tripping element **820** operates to pivot the arm **810**, the link **812** provides a dynamic force to the switch actuator **772** and the link **774** to ensure an efficient separation of the contacts **778** and **780** with a reduced amount of mechanical force than may otherwise be necessary. The tripping element actuator **820** engages the pivot arm **810** at a good distance from the pivot point of the arm **810** when mounted, and the resultant mechanical leverage provides sufficient mechanical force to overcome the static equilibrium of the mechanism when the switch contacts are in the opened or closed position. A compact and economical, yet highly effective tripping mechanism is therefore provided. Once the tripping mechanism operates, it may be quickly and easily reset by moving the switch actuator **772** back to the closed position that closes the switch contacts.

Suitable solenoids are commercially available for use as the tripping actuator element **820**. Exemplary solenoids include LEDEX® Box Frame Solenoid Size B17M of Johnson Electric Group (www.ledex.com) and ZHO-0520L/S Open Frame Solenoids of Zohnen Electric Appliances (www.zonhen.com). In different embodiments, the solenoid **820** may be configured to push the arm **810** and cause it to rotate, or to pull the contact arm **810** and cause it to rotate. That is, the tripping mechanism can be operated to cause the switch contacts to open with a pushing action on the pivot arm **810** as described above, or with a pulling action on the pivot arm **810**. Likewise, the solenoid could operate on elements other than the pivot arm **810** if desired, and more than one solenoid could be provided to achieve different effects.

In still other embodiments, it is contemplated that actuator elements other than a solenoid may suitably serve as a tripping element actuator to achieve similar effects with the same or different mechanical linkage to provide comparable tripping mechanisms with similar benefits to varying degrees. Further, while simultaneous actuation of the components described is beneficial, simultaneous activation of the interlock element **806** and the sliding bar **776** carrying the switch contacts **778**, **780** may be considered optional in some embodiments and these components could accordingly be independently actuated and separately operable if desired. Different types of actuator could be provided for different elements.

Moreover, while in the embodiment shown, the trip mechanism is entirely contained within the disconnect housing **752** while still providing a relatively small package size. It is recognized, however, that in other embodiments the tripping mechanism may in whole or in part reside outside the disconnect housing **752**, such as in separately provided modules that may be joined to the disconnect housing **752**. As such, in some embodiments, the trip mechanism could be, at least in part, considered an optional add-on feature provided in a module to be used with the disconnect housing **752**. Specifically, the trip element actuator and linkage in a separately provided module may be mechanically linked to the switch actuator **772**, the pivot arm **810** and/or the sliding bar **776** of the disconnect housing **752** to provide comparable functionality to that described above, albeit at greater cost and with a larger overall package size.

The tripping element **820** and associated mechanism may further be coordinated with a detection element and control circuitry, described further below, to automatically move the switch contacts **778**, **780** to the opened position when predetermined electrical conditions occur. In one exemplary embodiment, the second line terminal **782** is provided with an in-line detection element **830** that is monitored by control circuitry **850** described below. As such, actual electrical conditions can be detected and monitored in real time and the tripping element **820** can be intelligently operated to open the circuit path in a proactive manner independent of operation of the fuse module **754** itself and/or any manual displacement of the switch actuator **772**. That is, by sensing, detecting and monitoring electrical conditions in the line terminal **782** with the detection element **830**, the switch contacts **778**, **780** can be automatically opened with the tripping element **820** in response to predetermined electrical conditions that are potentially problematic for either of the fuse module **754** or the base assembly (i.e., the disconnect housing **752** and its components).

In particular, the control circuitry **850** may open the switch contacts in response to conditions that may otherwise, if allowed to continue, cause the primary fuse element in the fuse module **754** to permanently open and interrupt the electrical circuit path between the fuse terminals **758**. Such monitoring and control may effectively prevent the fuse module **754** from opening altogether in certain conditions, and accordingly save it from having to be replaced, as well as providing notification to electrical system operators of potential problems in the electrical power distribution system. Beneficially, if permanent opening of the fuse is avoided via proactive management of the tripping mechanism, the device **750** becomes, for practical purposes, a generally resettable device that may in many instances avoid any need to locate a replacement fuse module, which may or may not be readily available if needed, and allow a much quicker restoration of the circuitry than may otherwise be possible if the fuse module **754** has to be replaced. It is recognized, however, that if certain circuit conditions were to occur, permanent opening of the fuse **754** may be unavoidable.

As shown in FIG. **31**, the detecting element **830** may be provided in the form of a low resistance shunt **830** that facilitates current sensing and measurement. The shunt **830** may be integrally provided in the line terminal **782** and provided for assembly of the disconnect device **750** as a single piece. In the example shown, the shunt **830** may be welded to a distal end **832** and a proximal end **834** of the terminal **782**. The connecting terminal **785** may likewise be integrally provided with the terminal **782** or may alternatively be separately attached. In exemplary embodiments, the shunt **830** may be a 100 or 200 micro Ohm shunt element. The shunt element is placed in-line (i.e. is electrically connected in series) with the current path in the line terminal **782**, rather than in a parallel current path (i.e., a path electrically connected in parallel with the circuit path established through the device **750**). In another embodiment, however, current may be detected along a parallel current path if desired, and used for control purposes in a similar manner to that described below.

FIG. **32** illustrates an exemplary first line terminal **764** for the device **750** shown in FIG. **30**. As shown in FIG. **32**, the first line terminal **764** includes the contact **766** at one end thereof, and an integrally formed fuse clip **760**. The fuse clip

760 is cut from a section **836** and shaped or bent into the configuration shown. A spring element **838** is further provided on the fuse clip **760**. While the integrally formed fuse clip **760** is beneficial from manufacturing and assembly perspectives, it is understood that the line side fuse clip **760** could alternatively be separately provided and attached to the remainder of the terminal if desired.

The terminals **782** and **764** shown in FIGS. **31** and **32** are examples only. Other terminal configurations are possible and may be used. It is understood that the shunt element **830** may be provided in the terminal **764** instead of the terminal **782**, or perhaps elsewhere in the device **750**, with similar effect.

As shown in FIGS. **30**, **33** and **34** the device **750** further includes a neutral terminal or neutral connection **852** that facilitates operation of processor-based electronic control circuitry **850** for control purposes. As seen in FIG. **34**, the line side circuitry **790** may be, for example, operating at 120 VAC. The control circuitry **850** may include, as shown in FIG. **34** a first circuit board **854** and a second circuit board **856**. The first circuit board **854** includes step down components and circuitry **858** and analog to digital conversion components and circuitry **860** such that the first board **854** may supply direct current (DC) power to the second board **856** at reduced voltage, such as 24 VDC. The first board is accordingly sometimes referred to as a power supply board **854**. Because the power supply board **854** draws power from the line side circuitry **790** operating at a higher voltage, the control circuitry **850** need not have an independent power supply, such as batteries and the like or a separately provided power line for the electronic circuitry that would otherwise be necessary. While exemplary input and output voltages for the power supply board are discussed, it is understood that other input and output voltages are possible and depend in part on specific applications of the device **750** in the field.

The second board **856** is sometimes referred to as a processing board. In the exemplary embodiment shown, the processing board **856** includes a processor-based microcontroller including a processor **862** and a memory storage **864** wherein executable instructions, commands, and control algorithms, as well as other data and information required to satisfactorily operate the disconnect device **750** are stored. The memory **864** of the processor-based device may be, for example, a random access memory (RAM), and other forms of memory used in conjunction with RAM memory, including but not limited to flash memory (FLASH), programmable read only memory (PROM), and electronically erasable programmable read only memory (EEPROM).

As used herein, the term "processor-based" microcontroller shall refer not only to controller devices including a processor or microprocessor as shown, but also to other equivalent elements such as microcomputers, programmable logic controllers, reduced instruction set (RISC) circuits, application specific integrated circuits and other programmable circuits, logic circuits, equivalents thereof, and any other circuit or processor capable of executing the functions described below. The processor-based devices listed above are exemplary only, and are thus not intended to limit in any way the definition and/or meaning of the term "processor-based".

While the circuitry **850** is shown in FIG. **33** as residing internally to the disconnect housing **752** and is entirely contained therein, it could alternatively be provided in whole or in part outside the disconnect housing **752**, such as in separately provided modules that may be joined to the disconnect housing **752**. The detecting element **830**, while also shown as residing in the disconnect housing **752**, could likewise be provided outside the housing in a separately provided module that may or may not include the control circuitry **850**.

The detecting element **830** senses the line side current path in the first line terminal **830** and provides an input to the processing board **856**. Thus, the control circuitry **850**, by virtue of the detecting element **830**, is provided with real time information regarding current passing through the line terminal **782**. The detected current is then monitored and compared to a baseline current condition, such as a time-current curve as further explained below, that is programmed into the circuitry (e.g., stored in the memory **864**). By comparing the detected current with the baseline current, decisions can be made by the processor **862**, for example, to operate a trip mechanism **866** such as the tripping element actuator **820** and related linkage described above in response to predetermined electrical conditions as further described below.

As shown in FIGS. **30**, **33** and **34** the disconnect device **750** may further include an indicator element **870** in the disconnect housing **752** to signify certain electrical conditions as they occur or different states of the disconnect device **750**. The indicator **870** may be, for example, a light emitting diode (LED), although other types of indicators are known and may be used. In one embodiment, the LED indicator **870** is operable in more than one mode to distinctly indicate different electrical events. For example, a flashing or intermittent illumination of the indicator **870** may indicate an overcurrent condition in the circuitry that has not yet opened the primary fuse element of the fuse module **754**, while a solid or continuous non-intermittent illumination may indicate a trip event wherein the tripping mechanism **866** has caused the switch contacts **778**, **780** to open or to indicate an open fuse condition. Of course, other indication schemes are possible using one or more indicator elements, whether or not LEDs.

As also shown in FIG. **34**, a remote signal device **880** may be further connected as an input to the circuitry **850**, and may serve as an override element to cause the tripping mechanism **866** to operate independently of any detected condition by the element **830**. In one contemplated arrangement, the remote signal device **880** could generate a 24V input signal at the neutral terminal **852**. The remote signal device **880** may be a processor based, electronic device such as those described above or another device capable of providing the input signal. Using the remote signal device **880**, the disconnect device **750** may be remotely tripped on demand in response to circuit events upstream or downstream of the device, to perform maintenance procedures, or for still other reasons.

The remote signal device **880** may be especially useful for coordinating different loads that may be connected to the control circuitry. In one such example, the load **794** may include a motor and a separately powered fan provided to cool the motor in use. If the device **750** is connected in series with the motor but not the fan, and if the device **750** operates to open the switch contacts to the motor, the signal device **880** can be used to switch the fan off. Likewise, if the fan ceases to operate, a signal can be sent with the remote signal device **880** to open the switch contacts in the device **750** and disconnect the motor in the load circuitry **794**.

As further shown in FIGS. **33** and **34**, an overvoltage module **890** may be provided and may be electrically connected in parallel to the load side circuitry **794**. Specifically, the overvoltage module **890** may be connected to the load side connecting terminal **768** and electrical ground. The overvoltage module **890** in contemplated embodiments may include a voltage-dependent, nonlinear resistive element such as a metal oxide varistor element and may accordingly be configured as a transient voltage surge suppression device or surge suppression device. A varistor is characterized by having a relatively high resistance when exposed to a normal operating voltage, and a much lower resistance when exposed to a larger voltage, such as is associated with over-voltage conditions. The impedance of the current path through the varistor is substantially lower than the impedance of the circuitry being protected (i.e., the load side circuitry **890**) when the device is operating in the low-impedance mode, and is otherwise substantially higher than the impedance of the protected circuitry. As over-voltage conditions arise, the varistor switches from the high impedance mode to the low impedance mode and shunt or divert over-voltage-induced current surges away from the protected circuitry and to electrical ground, and as over-voltage conditions subside, the varistor returns to a high impedance mode. The varistor may switch to the low impedance mode much more rapidly than the fuse module **754** could act to open the circuit through the device **150** to the load **794**, and the over-voltage element **890** therefore protects the load side circuitry **794** from transient over-voltage events that the fuse itself may not protect against.

FIG. **35** is an exemplary time-current curve for exemplary fuse modules useable with the device **750** in various embodiments. The curve is plotted from or otherwise represents a multitude of data points for time and current values, and the corresponding time-current curve data can be programmed into the controller memory **864** in a look-up table, for example, and may therefore be used as a guideline comparison for actual current conditions detected with the element **830**. As shown in FIG. **35**, the time current curve is logarithmic and includes current magnitude values in amperes on the vertical axis, and time magnitude values in seconds on the horizontal axis. A number of fuse modules of different current ratings in amperes are plotted on the graph. The exemplary fuse modules plotted in FIG. **35** are Low-Peak® CUBEFuse® Finger Safe, Dual Element, Time Delay Class J performance fuses of Cooper Bussmann, St. Louis, Mo. and having amperage ratings of 1-100 A. Such time-current curves are known and have been determined for many types of fuses, but to the extent not already determined such time-current curves could be empirically determined or theoretically established.

While multiple fuses are plotted in the example of FIG. **35**, for any given base assembly for the device **750** (i.e., the disconnect housing **752** and its components) only one plot, or set of data corresponding to one of the plots, for the most appropriately rated fuse need be provided for the control circuitry **850** to operate. Of course, more than one set of data corresponding to different curves may be provided if desired, as long as the control circuitry utilizes the proper set of data for any fuse used with the device. Each set of data may represent an entire time-current curve as shown in the example of FIG. **35**, or only a portion or range of one of the time-current curves depending on actual applications of the device of the field and electrical events of most interest.

It can be seen from the exemplary time-current curves of FIG. **35** that any of the fuses plotted can withstand substantially greater currents than the corresponding rated current for some period of time before opening. For example, considering the plotted curve for the 40 A rated fuse, the fuse module can withstand current magnitude levels approaching 500 A for approximately 1 second before opening. However, the same 40 A fuse module can withstand about 80 A of current for about 100 seconds before opening, or between 50 and 60 A for 1000 seconds before opening. Especially for longer duration overcurrent events, the plot can serve as a guide for the control circuitry to cause the trip mechanism **866** to operate in response to current conditions sustained for a period of time that is not yet sufficient to open the fuse element in the module, but is perhaps symptomatic of a problem in the electrical system.

By virtue of the detection element **830** providing a control input signal, the control circuitry **850** can compare not only the magnitude of actual current flowing through the device **750** (and hence flowing through the fuse module **754**) at any given point in time, but can measure the duration of the current flow in order to make control decisions. That is, the control circuitry **850** is configured to make time-based and magnitude-based decisions by comparing elapsed duration of actual current conditions (i.e., actual levels of current) to the predetermined time-current curve expectation for the fuse in use with the device **750**. Based on the magnitude and time duration of detected electrical current conditions, the control circuitry **850** can intelligently monitor and control operation of the device **750** in response to current conditions actually detected before the fuse module **754** permanently opens.

For example, default rules can be implemented with the processor **862** to determine one or more time-based and magnitude-based tripping points causing the circuitry **850** to operate the tripping mechanism **866** in response to detected electrical current conditions. In one exemplary scenario, if detected current conditions reach 150% of the rated current of the fuse module **754** actually used in the device **750** for a predetermined amount of time, which may be a predetermined percentage of the time indicated in the time-current curve at the detected current level, the trip mechanism may be actuated. As such, the trip mechanism **866** may be actuated in anticipation of the fuse module **754** opening. Alternatively, stated, the control circuitry **850** may open the switch contacts with the tripping mechanism **866**, based on the time-current curve as compared to detected current durations, in less time than the fuse module **754** would otherwise take to operate and open the circuit through the device **750**. The tripping of the mechanism **866** under such circumstances, which can be indicated with the indicator **870**, may serve as a prompt to troubleshoot the electrical system to determine the cause of the overcurrent, if possible. Once the device **750** is tripped in such a fashion, the fuse module **754** may or may not need to be replaced, depending on how close the tripping points are to the actual opening points of the fuse based on the applicable time-current curve.

Likewise, tripping points can be set at a point higher than the time-current curve may otherwise indicate to ensure that the switch contacts in the device **750** are opened in the event that a fuse module **754** withstands a given current level for a duration longer than would be expected from the time-current curve. Thus, considering the exemplary time-current curve for the 40 A rated fuse in FIG. **35**, if a 40 A rated fuse module withstands an actual 60 A current as detected with the element **830** for a duration of 300 seconds, the control circuitry can decide to operate the tripping mechanism **866** because according to the time-current curve, the fuse would have been expected to operate and open at about 200 seconds, well prior to expiration of the 300 second period. Such a scenario could represent a condition wherein a fuse having an inappropriately high current rating has been installed, or perhaps an atypical performance of the fuse of the proper rating. In any event, the control circuitry **850** could emulate the performance of the properly rated fuse, or a more typically performing fuse of the proper rating, in such circumstances.

In accordance with the foregoing examples, the control circuitry **850** can respond to threshold deviations between actual detected current and the baseline current from the time-current curve, either directly or indirectly utilizing tripping points offset from the time-current curve. By monitoring time and current conditions, and by comparing actual current conditions to the time-current curve, and also with some strategic selection of the threshold tripping points, the control circuitry **850** can be tailored to different sensitivities for different applications, and may even detect unusual or unexpected operating conditions and accordingly trip the device **750** to prevent any associated damage to the load side circuitry **794**.

Of course, the comparison of detected time and current parameters to the predetermined time-current curve can confirm also an unremarkable or normal operating state of the fuse **754** and the device **750**. For example, a 40 A rated fuse could operate at a 40 A current level or below indefinitely without opening, and the control circuitry **850** would in such circumstances take no action to operate the trip mechanism **866**.

Having now described the control circuitry **850** functionally, it is believed those in the art could implement the functionality described with appropriate circuitry and appropriately programmed operating algorithms without further explanation.

FIG. **36** is a side elevational view of a portion of a fifteenth embodiment of a fusible switching disconnect device **900** that in many ways is similar to the device **750** described above, and hence like reference characters of the devices **750** and **900** are indicated with like reference characters in the Figures. Common features of the devices **750** and **900** will not be separately described herein, and the reader is referred back to the device **750** and the discussion above.

Unlike the device **750**, the device **900** has a different detecting element **902**. That is, the shunt element **830** is replaced with another and different type of detecting element **902** in the form of a Hall Effect sensor. As shown in FIG. **37**, the Hall Effect sensor **902** is integrally provided in the line terminal **782** having the stationary contact **784**. The Hall Effect sensor **902** may be used in lieu of the control element **830** to provide feedback to the control circuitry **850** described above to intelligently monitor and control the tripping mechanism **866** in a similar manner to that described above. An exemplary Hall Effect sensor suited for use as the detection element **902** includes an ACS758×CB Hall Effect-based sensor of Allegro MicroSystems, Inc., Worcester, Mass.

As still another option, and as also shown in FIG. **36**, a current transformer **910** could be provided in lieu of or in addition to the Hall Effect sensor **902** to detect current flow and provide feedback to the control circuitry **850**. The current transformer **910** could be located interior or exterior to the device **900** in different embodiments. A suitable current transformer for use as the element **910** includes a CT1002 Current Transformer and a CT1281 Current Transformer available from Electroohms Pvt., Ltd., Banagalore, India.

While the control circuitry **850** described is responsive to current sensing using resistive shunts, Hall Effect sensors or current transformers providing control inputs to the circuitry **850**, similar functionality could be provided using sensor or detection elements corresponding to other electrical circuit conditions. For example, because voltage and current are linearly related, voltage sensing inputs could be used and current values could be readily calculated therefrom for use by the control circuitry **850**. Still further, voltage sensors could be used to make time-based and magnitude-based comparisons in a similar manner to those described above without first having to calculate current values. In such embodiments, time-current curves and data sets may be omitted in favor of other baseline curves or data sets, which may or may not be conversions of time-current curves, that may be used to directly or indirectly set time-based and magnitude-based threshold tripping points. As such, tripping points utilized by the control circuitry need not be derived from time-current curves, but can be established in light of other considerations for specific end uses or to meet different specifications.

The advantages and benefits of the invention are now believed to have been amply demonstrated in the exemplary embodiments disclosed.

An embodiment of a fusible switch disconnect device has been disclosed including: a disconnect housing adapted to receive and engage at least a portion of a removable electrical fuse, the fuse including first and second terminal elements and a fusible element electrically connected therebetween, the fusible element defining a circuit path and being configured to permanently open the circuit path in response to predetermined electrical current conditions experienced in the circuit path; line side and load side terminals in the disconnect housing and electrically connecting to the respective first and second terminal elements of the fuse when the fuse is received and engaged with the disconnect housing; at least one switchable contact in the disconnect housing, the at least one switchable contact provided between one of the line side terminal and load side terminal and a corresponding one of the first and second terminal elements of the fuse, the at least one switchable contact selectively positionable in an open position and a closed position to respectively connect or disconnect an electrical connection between the line side terminal and the load side terminal and through the circuit path of the fusible element; and a mechanism operable to automatically cause the at least one switchable contact to move to the open position in response to a predetermined electrical condition when the line side terminal is connected to energized line circuitry.

Optionally, the fusible switch disconnect device of claim may also include a detecting element configured to detect the predetermined electrical condition. The electrical condition may include one of a voltage condition and a current condition. In an embodiment wherein the electrical condition is a voltage condition, the detecting element may be configured to monitor one of an undervoltage condition and an overvoltage condition.

A microcontroller may be provided in communication with the detection element and the microcontroller may cause the mechanism to move the switchable contact in response to detection of the predetermined electrical condition. The microcontroller may be configured to compare an actual electrical condition as detected with the detection element to a baseline operating condition, and when the compared electrical condition deviates from the baseline electrical condition by a predetermined threshold, the microcontroller may operate the mechanism to move to the open position. The baseline operating condition may include a time-current curve.

As further options, the microcontroller may be provided on a first circuit board in the disconnect housing, with the fusible switch disconnect device further comprising a second circuit board in the disconnect housing, wherein the second circuit board supplies power to the first circuit board. The second circuit board may be connected to one of the line and load side terminals and may receive power therefrom. The second circuit board may be configured to receive AC power from one of the line and load side terminals and supply DC power to the first circuit board. The second circuit board may also be configured to step down the power supply from one of the line and load side terminals and supply the stepped down power to the first circuit board.

The mechanism may optionally include a solenoid, and the solenoid may be responsive to the microcontroller and cause displacement of the switchable contact from the closed position. The detecting element may be configured to sense current flow through the closed switchable contact, and may be one of a Hall Effect sensor, a current transformer, and a shunt. The detecting element may monitor a current path in the disconnect device at a location between the at least one switchable contact and one of the line and load side terminals.

A neutral connecting terminal may also be optionally provided in the fusible switch disconnect device, and the microcontroller may be electrically connected to the neutral terminal. An overvoltage detecting element may also optionally be provided, and the overvoltage detecting element may be connected between one of the line and load side terminals and the neutral terminal.

Also optionally, an indicator responsive to the microcontroller may further be provided to indicate the electrical condition. The indicator may be a light emitting diode. The indicator may further be operable in at least two distinct modes, including a continuous indication mode and an intermittent indication mode.

In an embodiment wherein the detecting element includes a resistive shunt, it may optionally be integrally provided in a conductive terminal element extending between the switchable contact and one of the line and load side terminals.

The at least one switchable contact in the fusible switch disconnect device may optionally include a pair of movable contacts, and the movable contacts may be biased to an open position. The fuse in the fusible switch disconnect device may include a rectangular fuse module having plug-in terminal blades engageable with the disconnect housing. The fuse may be directly receivable and engageable with the disconnect housing without utilizing a separately provided fuse carrier.

The mechanism in the fusible switch disconnect device may optionally include an electromagnetic coil including a cylinder extendable and retractable along an axis of the coil. A rotatable arm may be provided in the fusible switch disconnect device and may be positioned proximate the electromagnetic coil, wherein the rotatable arm may be displaced when the cylinder is extended.

Another embodiment of a fusible switch disconnect device has also been disclosed including: a disconnect housing adapted to receive and engage at least a portion of a removable electrical fuse, the fuse including first and second terminal elements and a fusible element electrically connected therebetween, the fusible element defining a circuit path and being configured to permanently open the circuit path in response to predetermined electrical current conditions experienced in the circuit path; at least a first terminal in the disconnect housing associated with the circuit path when the fuse when the fuse is received and engaged with the disconnect housing; at least one switchable contact in the disconnect housing and associated with the first terminal, the at least one switchable contact selectively positionable in an open position and a closed position to respectively connect or disconnect an electrical connection through the circuit path of the fusible element; and electronic circuitry configured to: monitor current flow through at least one of the first terminal and the circuit path of the fusible element; and compare the monitored current flow to a baseline operating condition, wherein the baseline operating condition comprises at least one set of time-current data associated with operation of the fuse.

Optionally, the disconnect housing may include a line side terminal and a load side terminal respectively engageable to the first and second terminal elements of the fuse, and the at least one switchable contact may include a first switchable contact provided on one of the line side and load side terminal. The fusible switch disconnect device may further include a line side connecting terminal and a load side connecting terminal respectively providing line side and load side connections to line and load electrical circuitry, and the at least one switchable contact may include a second switchable contact provided on one of the line and load side connecting terminals. A detecting element may be associated with one of the line and load side connecting terminals, and the detecting element may provide a signal input to the electronic circuitry, thereby allowing the current flow to be monitored. The detecting element may include at least one a resistive shunt, a current transformer, and a Hall Effect sensor.

Optionally, the fusible switch disconnect device of claim **29**, may further include a mechanism, responsive to the electronic circuitry, to automatically cause the at least one switchable contact to move to the open position if the compared monitored current flow deviates from the baseline operating condition by a predetermined amount. The mechanism may include a solenoid responsive to the electronic circuitry. The electronic circuitry may include a power supply board and a processing board.

A local state indicator may also optionally be provided, and may be configured to visually indicate a deviation of the monitored current flow to a baseline operating condition while the at least one switchable contact is in the closed position. The local state indicator may include a light emitting diode, and the electronic circuitry may cause the light emitting diode to flash intermittently to indicate the deviation.

The fusible switch disconnect device of claim may optionally further include a neutral terminal and a remote signal device in communication with the neutral terminal. An over-voltage detecting element may be coupled to the electronic circuitry, and the over-voltage detecting element may include a varistor element. The electronic circuitry may optionally include a microcontroller, and the removable electrical fuse may include a rectangular fuse module having plug-in terminal blades.

Another embodiment of a fusible switch disconnect device has also been disclosed, including: housing means for receiving an overcurrent protection fuse; terminal means for establishing a circuit path through the overcurrent protection fuse; switching means for connecting and disconnecting the circuit path; overcurrent detecting means for sensing electrical current flow in the circuit path; and controller means for making a time-based and magnitude-based comparison of sensed current flow versus a predetermined time-based and magnitude-based baseline for the overcurrent protection fuse.

A means for operating the switching means in response to the time-based and magnitude based comparison may further be optionally provided. An over-voltage detecting means for detecting an over-voltage condition in the circuit path may also be provided, and so may a remote signaling means for over-riding the controller means. Local indication means may be provided for indicating a deviation in the time-based and magnitude-based comparison.

An embodiment of a fusible switch disconnect device has likewise been disclosed including: a housing configured to receive a removable overcurrent protection fuse; terminals establishing a circuit path through the housing and the fuse when the fuse is received; a detecting element configured to sense an electrical condition in the circuit path; and a processor-based control element configured to undertake a time-based and magnitude-based comparison of the sensed electrical condition in the current path and a predetermined time-based and magnitude-based electrical condition baseline.

Optionally, the fusible switch disconnect device may also include switch contacts for connecting and disconnecting a portion of the circuit path, and the control element may cause automatic positioning of the switch contacts to disconnect the circuit path in response to the time-based and magnitude based comparison. The detecting element may be configured to sense current in the circuit path. The electrical condition baseline may include a set of current magnitude values and time values for each current magnitude level. The set of current magnitude values and time values may be derived from a time-current curve for the overcurrent protection fuse.

Also optionally, the electrical condition baseline may include at least one set of electrical condition magnitude values and time values for each electrical condition magnitude level, and the controller may position the switch contacts based on both the electrical condition magnitude values and the time values in the set. The data set may define at least a portion of a curve in a predefined relationship of the electrical current condition and a state of the overcurrent protection fuse. The predefined relationship may be a time-current curve. The overcurrent protection fuse may be configured for plug in electrical connection to complete the current path.

While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.

What is claimed is:

1. A circuit protection device comprising:

a fusible switch disconnect assembly, the fusible switch disconnect assembly comprising:

a switch housing adapted to accept at least a portion of a compatible time delay fuse with plug-in connection, the compatible time delay fuse including first and second terminal blade elements and a fusible element electrically connected therebetween, the fusible element defining a circuit path having a predetermined current rating and that is configured to permanently open according to a continuous time-current curve;

line side and load side terminals in the switch housing and electrically connecting to the respective first and second terminal blade elements when the at least the portion of the compatible time delay fuse is accepted with plug-in connection in the switch housing;

a pair of stationary switch contacts and a pair of movable switch contacts in the switch housing, the pair of stationary switch contacts provided between the line side terminal and the first terminal blade element of the compatible time delay fuse, the pair of movable switch contacts selectively positionable in an open position and a closed position to respectively disconnect or connect an electrical connection through the circuit path of the fusible element of the compatible time delay fuse;

a mechanism operable to cause the pair of movable switch contacts to automatically move to the open position, wherein the mechanism comprises an electromagnetic coil and a linkage engageable by the electromagnetic coil when the electromagnetic coil is energized;

a detecting element configured to detect an actual electrical current flow through the circuit path of the fusible element; and

a controller responsive to the detected actual electrical current flow and in communication with the electromagnetic coil, the controller configured to respond to a detected longer duration overcurrent event where the detected actual electrical current flow through the current path of the fusible element is above the predetermined current rating for a period of time without causing the fusible element to open while the pair of movable switch contacts are in the closed position by:

comparing an elapsed duration of the detected actual electrical current flow that is above the predetermined current rating in the longer duration overcurrent event with a corresponding portion of the continuous time-current curve of the compatible time delay fuse that is accepted with plug-in connection in the switch housing; and

when a deviation between the compared elapsed duration of the detected actual electrical current flow that is above the predetermined current rating and the corresponding portion of the continuous time-current curve exceeds a predetermined threshold in the longer duration overcurrent event, proactively energizing the electromagnetic coil to move the pair of movable switch contacts to the open position, thereby avoiding a permanent opening of the fusible element in the compatible time delay fuse that is accepted with plug-in connection in the switch housing, and whereby the fusible switch disconnect assembly is resettable and avoids a need to replace the compatible time delay fuse because of the detected longer duration overcurrent event.

2. The circuit protection device of claim **1**, wherein the fusible switch disconnect assembly further comprises a first circuit board and a second circuit board, wherein the controller is provided on the first circuit board and wherein the second circuit board supplies power to the first circuit board.

3. The circuit protection device of claim **2**, wherein the second circuit board is connected to one of the line side and load side terminals and receives power therefrom.

4. The circuit protection device of claim **3**, wherein the second circuit board is configured to receive AC power from one of the line side and load side terminals and supply DC power to the first circuit board.

5. The circuit protection device of claim **4**, wherein the second circuit board is configured to step down the power supply from one of the line side and load side terminals and supply the stepped down power to the first circuit board.

6. The circuit protection device of claim **1**, wherein the electromagnetic coil comprises a solenoid.

7. The circuit protection device of claim 1, wherein the fusible switch disconnect assembly further comprises an indicator responsive to the controller to indicate the detected longer duration overcurrent event.

8. The circuit protection device of claim 7, wherein the indicator is a light emitting diode.

9. The circuit protection device of claim 7, wherein the indicator is operable in at least two distinct modes.

10. The circuit protection device of claim 9, wherein the at least two distinct modes includes a continuous indication mode and an intermittent indication mode.

11. The circuit protection device of claim 1, wherein the fusible switch disconnect assembly further comprises a neutral terminal, the controller electrically connected to the neutral terminal.

12. The circuit protection device of claim 11, wherein the fusible switch disconnect assembly further comprises an overvoltage detecting element, the overvoltage detecting element connected between one of the line side and load side terminals and the neutral terminal.

13. The circuit protection device of claim 1, wherein the detecting element is a Hall Effect sensor, a current transformer, or a shunt.

14. The circuit protection device of claim 1, wherein the detecting element comprises a resistive shunt integrally provided in a conductive terminal element in the switch housing.

15. The circuit protection device of claim 1, wherein the pair of movable switch contacts are spring biased to the open position.

16. The circuit protection device of claim 1, wherein the compatible time delay fuse comprises a rectangular fuse module, the terminal blade elements projecting from a common side of the rectangular fuse module and being spaced apart from one another.

17. The circuit protection device of claim 1, wherein the electromagnetic coil comprises a cylinder extendable and retractable along a first axis, and the pair of movable switch contacts being displaced along a second axis perpendicular to the first axis.

18. The circuit protection device of claim 1, wherein the compatible time delay fuse is a Class J fuse.

19. The circuit protection device of claim 1, wherein the compatible time delay fuse has an amperage rating of 1-100 A.

20. The circuit protection device of claim 1, wherein the predetermined threshold is a percentage of the time indicated in the continuous time-current curve at a current magnitude equal to the actual electrical current flow.

21. The circuit protection device of claim 1, wherein the predetermined threshold exceeds the time indicated in the continuous time-current curve at a current magnitude equal to the actual electrical current flow.

22. A circuit protection device comprising:

a fusible switch disconnect assembly comprising:

a disconnect housing adapted to receive and engage at least a portion of a removable time delay overcurrent protection fuse, the removable time delay overcurrent protection fuse including first and second terminal elements and a fusible element electrically connected therebetween, the fusible element defining a circuit path having a predetermined current rating and being configured to permanently open the circuit path in response to a predetermined overcurrent condition when experienced in the circuit path;

a first fuse terminal in the disconnect housing to establish a connection to the first terminal element of the removable time delay overcurrent protection fuse when the first terminal element is engaged with the first fuse terminal;

a line side terminal in the disconnect housing being configured to establish an electrical connection to a line side electrical circuit;

a first switch contact in the disconnect housing and provided on the first fuse terminal;

a second switch contact in the disconnect housing and provided on the line side terminal;

a pair of switchable contacts selectively positionable relative to the first and second switch contacts in an open position and a closed position to respectively disconnect or connect an electrical connection between the first and second switch contacts; and

electronic circuitry configured to avoid a permanent opening of the fusible element in a longer duration overcurrent event above the predetermined current rating and thereby providing a resettable fusible switch disconnect assembly that does not require replacement of the removable time delay overcurrent protection fuse due to the longer duration overcurrent event by:

monitoring, while the removable time delay overcurrent protection fuse remains received and engaged with the disconnect housing, an elapsed current flow above the predetermined current rating through the line side terminal; and

comparing, in the longer duration overcurrent event, the monitored elapsed current flow through the line side terminal to a baseline set of time-current data representing an expectation for permanent opening of the fusible element in the removable time delay overcurrent protection fuse that is received and engaged with the disconnect housing.

23. The circuit protection device of claim 22, wherein the fusible switch disconnect assembly further includes a second fuse terminal being configured to establish a connection to the second terminal element of the removable time delay overcurrent protection fuse when the second terminal element is engaged with the second fuse terminal.

24. The circuit protection device of claim 23, wherein the fusible switch disconnect assembly further comprises a current detecting element associated with the line side terminal, the current detecting element providing a signal input to the electronic circuitry.

25. The circuit protection device of claim 24, wherein the current detecting element comprises a resistive shunt, a current transformer, or a Hall Effect sensor.

26. The circuit protection device of claim 22, wherein the fusible switch disconnect assembly further comprises a mechanism responsive to the electronic circuitry and configured to automatically cause the pair of switchable contacts to move to the open position when the compared monitored elapsed current flow in the longer duration overcurrent event deviates from the baseline set of time-current data by a predetermined amount.

27. The circuit protection device of claim 26, wherein the mechanism includes a solenoid responsive to the electronic circuitry.

28. The circuit protection device of claim 22, wherein the electronic circuitry includes a power supply board and a processing board.

29. The circuit protection device of claim 22, wherein the fusible switch disconnect assembly further comprises a local state indicator configured to visually indicate a deviation of

the monitored elapsed current flow to the baseline set of time-current data while the pair of switchable contacts are in the closed position.

30. The circuit protection device of claim **29**, wherein the local state indicator comprises a light emitting diode, and the electronic circuitry causes the light emitting diode to flash intermittently to indicate the deviation.

31. The circuit protection device of claim **22**, further comprising a neutral terminal and a remote signal device in communication with the neutral terminal.

32. The circuit protection device of claim **22**, wherein the fusible switch disconnect assembly further comprises an over-voltage detecting element coupled to the electronic circuitry.

33. The circuit protection device of claim **32**, wherein the over-voltage detecting element comprises a varistor element.

34. The circuit protection device of claim **22**, wherein the electronic circuitry includes a microcontroller.

35. The circuit protection device of claim **22**, wherein the removable time delay overcurrent protection fuse comprises a rectangular fuse module having plug-in terminal blades.

36. The circuit protection device of claim **22**, wherein the removable time delay overcurrent protection fuse is a Class J fuse.

37. The circuit protection device of claim **22**, wherein the removable time delay overcurrent protection fuse has an amperage rating of 1-100 A.

38. The circuit protection device of claim **26**, wherein the predetermined amount is a percentage of the time indicated in the continuous time-current curve at a current magnitude equal to the monitored elapsed current flow.

39. The circuit protection device of claim **26**, wherein the predetermined amount exceeds the time indicated in the continuous time-current curve at a current magnitude equal to the monitored elapsed current flow.

40. The circuit protection device of claim **26**, wherein the mechanism is configured to automatically cause the pair of switchable contacts to move to the open position when the monitored elapsed current flow in the longer duration over-current event exceeds the baseline set of time-current data by a predetermined amount.

41. A circuit protection device comprising:

a fusible switch disconnect assembly comprising:

a housing configured to removably receive a compatible time delay overcurrent protection fuse having a predetermined current rating;

a switch in the housing, the switch including first and second movable contacts linked to one another and being simultaneously movable and selectively positionable in the housing between opened and closed positions;

terminals establishing a circuit path through the housing that is completed by the first and second movable contacts of the switch and the compatible time delay overcurrent protection fuse when the compatible time delay overcurrent protection fuse is received in the housing and when the first and second movable contacts are in the closed position;

a detecting element configured to sense an actual elapsed electrical current flow in the circuit path that is completed by the compatible time delay overcurrent protection fuse and the first and second movable contacts of the switch; and

a processor-based control element configured to proactively operate the switch, while the compatible time delay overcurrent protection fuse remains received and engaged with the housing, to avoid a permanent opening of the compatible time delay overcurrent protection fuse in a detected longer duration overcurrent event with actual elapsed electrical current flow above the predetermined current rating by:

operating the switch to open the current path in the detected longer duration overcurrent event via an assessment of the sensed actual elapsed electrical current flow above the predetermined current rating in the longer duration overcurrent event relative to a continuous time-current curve for the compatible time delay overcurrent protection fuse that is received and engaged with the housing, thereby providing a resettable fusible switch disconnect assembly that does not require a replacement of the time delay compatible electrical fuse.

42. The circuit protection device of claim **41**, wherein the compatible time delay overcurrent protection fuse is configured with terminal blades facilitating plug in electrical connection to complete the current path.

43. The circuit protection device of claim **41**, wherein the compatible time delay overcurrent protection fuse is a Class J fuse.

44. The circuit protection device of claim **41**, wherein the compatible time delay overcurrent protection fuse has an amperage rating of 1-100 A.

45. The circuit protection device of claim **41**, wherein the assessment of the sensed actual elapsed electrical current flow above the predetermined current rating in the longer duration overcurrent event relative to a continuous time-current curve for the compatible time delay overcurrent protection fuse that is received and engaged with the housing comprises an assessment of whether a duration of the sensed actual electrical current flow exceeds a corresponding duration according to the continuous time-current curve at a current magnitude equal to the sensed actual electrical current flow.

46. The circuit protection device of claim **41**, wherein the assessment of the sensed actual elapsed electrical current flow above the predetermined current rating in the longer duration overcurrent event relative to a continuous time-current curve for the compatible time delay overcurrent protection fuse that is received and engaged with the housing comprises an assessment of whether a duration of the sensed actual electrical current flow is approaching a corresponding duration according to the continuous time-current curve at a current magnitude equal to the sensed actual electrical current flow.

47. A circuit protection device comprising:

a fusible switch disconnect assembly comprising:

a housing and conductive terminals in the housing configured to define and complete a switchable circuit path between a line side electrical circuit and a load side electrical circuit and through an overcurrent protection device in the form of a removable electrical fuse including a fusible element and having a predetermined current rating; and

a processor-based control element configured to provide a resettable fusible switch disconnect assembly without having to replace the removable electrical fuse in a longer duration overcurrent event with a current above the predetermined current rating by:

monitoring a sensed electrical condition in the switchable circuit path in order to detect the longer duration overcurrent event;

undertaking a time-based and magnitude-based comparison of the sensed actual elapsed electrical condition in the switchable circuit path in the detected longer duration overcurrent event and a predetermined time-based and magnitude-based expectation for permanent opening of the fusible element connected to the switchable circuit path; and

opening the switchable circuit path when the time-based and magnitude-based comparison of the sensed actual elapsed electrical condition in the switchable circuit path and the predetermined time-based and magnitude-based expectation for permanent opening of the fusible element deviates by a predetermined amount in the longer duration overcurrent event.

48. The circuit protection device of claim **47**, wherein the removable electrical fuse is a time delay fuse.

49. The circuit protection device of claim **47**, wherein the removable electrical fuse is a Class J fuse.

50. The circuit protection device of claim **47**, wherein the removable electrical fuse has an amperage rating of 1-100 A.

51. The circuit protection device of claim **47**, wherein the predetermined amount corresponds to a percentage of the time indicated in the predetermined time-based and magnitude-based expectation for permanent opening of the fuse fusible element for the sensed electrical condition.

52. The circuit protection device of claim **47**, wherein the predetermined amount exceeds the time indicated in the predetermined time-based and magnitude-based expectation for permanent opening of the fuse fusible element for the sensed electrical condition.

53. A circuit protection device comprising:

a fusible switch disconnect assembly comprising:

a housing configured to receive at least a portion of a removable electrical fuse including a fusible element and having a predetermined current rating;

a first conductive terminal and a second conductive terminal mounted stationary in the housing, the first and second conductive terminal each defining respective first and second portions of a circuit path in the housing;

wherein a respective end of each of the first conductive terminal and the second terminal element includes a switch contact facilitating a switchable connection and disconnection of the first conductive terminal and the second conductive terminal;

wherein when the removable electrical fuse is received in the housing, the fusible element is connected in series with the first conductive terminal and the second conductive terminal;

a third conductive terminal mounted stationary in the housing, the third conductive terminal defining a third portion of the circuit path in the housing, wherein when the removable electrical fuse is received in the housing, the third terminal is connected in series to the fusible element;

a sensor configured to detect an actual flow of electrical current to the fusible element via the first conductive terminal and the second conductive terminal; and

a controller configured to respond to a longer duration overcurrent event by:

comparing, when the actual flow of electrical current detected with the sensor is above the predetermined current rating, the actual flow of current to a set of predetermined electrical current condition set points derived from a continuous time-current curve for the removable electrical fuse that is connected between the second and third conductive terminals; and

switchably disconnecting the first conductive terminal and the second conductive terminal when the actual flow of electrical current above the predetermined current rating corresponds to the one of the predetermined electrical condition set points in the longer duration overcurrent event, thereby providing a resettable fusible switch disconnect assembly without having to replace the removable electrical fuse because of the actual flow of current in the longer duration overcurrent event.

54. The circuit protection device of claim **53**, wherein the removable electrical fuse is a time delay fuse.

55. The circuit protection device of claim **53**, wherein the removable electrical fuse is a Class J fuse.

56. The circuit protection device of claim **53**, wherein the removable electrical fuse has an amperage rating of 1-100 A.

57. The circuit protection device of claim **53**, wherein the set of predetermined electrical current condition set points includes at least one set point that corresponds to a percentage of the time indicated in the continuous time-current curve at a current magnitude equal to the actual electrical current flow.

58. The circuit protection device of claim **53**, wherein the set of predetermined electrical current condition set points includes at least one set point that exceeds the time indicated in the continuous time-current curve at a current magnitude equal to the actual electrical current flow.

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